MISSISSIPPIAN SERIES OF EASTERN KENTUCKY

CHARLES BUTTS

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WILLARD ROUSE JILLSON
DIRECTOR AND STATE GEOLOGIST

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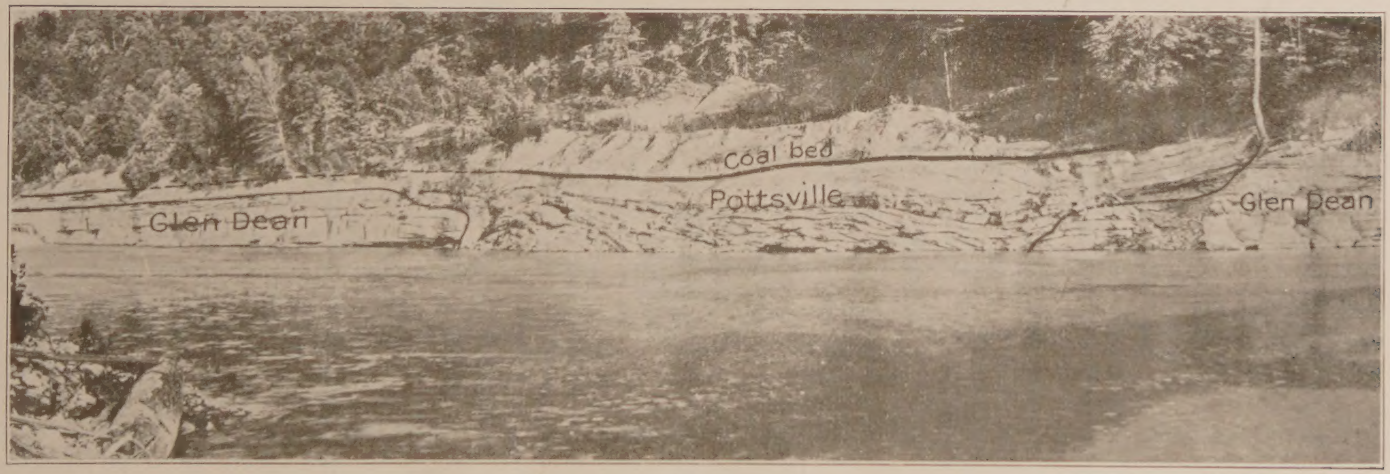

ANCIENT VALLEY IN THE GLEN DEAN LIMESTONE FILLED WITH POTTSVILLE SANDSTONE AND COAL BEDS.

View of a pre-Pottsville erosion channel in the Glen Dean limestone occupied by Pottsville sandstone with thin coal beds. Heidelberg, Ky., about four miles southwest of Beattyville. Pottsville-Glen Dean contact marked by ink line. Coal bed also marked with heavier line.

The MISSISSIPPIAN SERIES *of* EASTERN KENTUCKY

A Regional Interpretation of the Stratigraphic Relations of the Sub-carboniferous group based on new and detailed field examinations.

BY

CHARLES BUTTS

ASSISTANT GEOLOGIST

PREPARED IN CO-OPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY

Illustrated with Ninety-three Photographs, Maps and Diagrams

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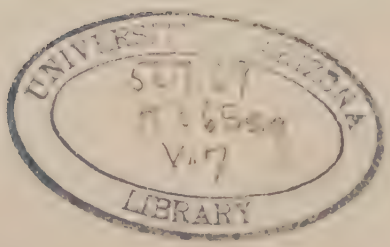

Letter of Transmission

Nov. 12, 1921.

DR. W. R. JILLSON:
Director and State Geologist,
Kentucky Geological Survey,
Frankfort, Ky.

DEAR DOCTOR JILLSON:

Under separate cover, I am sending to you by registered mail the manuscript, maps and other illustrations for a report by Charles Butts on "The Mississippian Series of Eastern Kentucky." This report is based upon work done in cooperation with the Kentucky Geological Survey and should bear appropriate acknowledgment. It completes, I believe, the report matter, resulting from the cooperative project, to be published by the State.

Very truly yours,

GEORGE OTIS SMITH,
Director.

Dept. of the Interior,
U. S. Geological Survey,
Washington, D. C.

65310

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The Mississippian Series *of* Eastern Kentucky

CHAPTER I.

Introduction

This report is a companion to the report on the Mississippian series of western Kentucky by E. O. Ulrich and the writer, published by the Kentucky Geological Survey in 1917. In that report the Mississippian series as developed in the western half of Kentucky or west of the meridian of Louisville was described. This report covers the belt of country occupied by the outcrop of the Mississippian rocks extending from the Louisville country to Tennessee and thence northward between the "Coal Measures" and the Bluegrass region to the Ohio River in Lewis and Greenup counties. (See key map on section chart.) It sets forth the classification, order, character, thickness, geographic extent, and regional variations of the various stratigraphic units into which the Mississippian series of that part of Kentucky is divided. As preliminary to the detailed description of the formations a definition and brief general description of the Mississippian series is given.

Name and Definition. The Mississippian series was first defined by Williams[1] in 1891, from the Mississippi Valley, where it is typically developed. The name was a modification of Mississippi group or series of Winchell.[2] It is the lowest of the three divisions of the Carboniferous system, the middle division being the Pennsylvanian series or "Coal Measures," represented by the coal-bearing shales and sandstones of the Kentucky coal fields; and the upper division being the Permian series, which is not represented in Kentucky. Briefly stated, the Mississippian series as usually understood in Mississippi and Ohio valleys is the body of stratified rocks lying between the well-known persistent black shale below and the "Coal Measures" above. In Ohio and northeastern Kentucky the main body of black shale is known as the Ohio shale; in southern and eastern Kentucky, in Tennessee, Alabama, and southern Illinois the black shale is known as the Chattanooga shale; and in the Louisville, Ky., region and in Indiana it is known as the New Albany shale.

[1] Williams, H. S., U. S. Geol. Survey Bull. 80, p. 135, 1891.
[2] Winchell, A., Am. Phil. Soc. Proc., Vol. 11, p. 79, 1869-70.

Some geologists believe that all of the black shale is of Devonian age. Other geologists believe that the greater part of the black shale, and in some regions all of it, is of Mississippian age. The precise location of the lower boundary of the Mississippian series is, therefore, a subject of doubt and discussion among geologists.

General Relations and Stratigraphy. The standard section and time scale of the Mississippian are based on its long-recognized and well-defined subdivisions in the Mississippi Valley, the type region. There at the bottom is the Kinderhook group, consisting of sandstone, shale, and limestone, but varying greatly from place to place in the relative thicknesses and order of succession of those elements, no two sections being alike. Its known thickness nowhere exceeds 100 feet. A section of the Kinderhook as it is at Burlington, Iowa, is given at the bottom of section No. 1 of the section chart.

The Kinderhook group is succeeded above by the Osage group, consisting of the Burlington limestone below and the Keokuk limestone above. Overlying the Osage is the Meramec group, which has been divided into the Warsaw limestone at bottom, the Spergen limestone in the middle, and the St. Louis limestone at top. The St. Louis limestone is followed above by the Ste. Genevieve limestone, by some included in the Meramec group and by others in the next overlying group, the Chester. The Chester group in its fullest development in Johnson County, Ill., as recently worked out by Stuart Weller of the University of Chicago, is composed of an alternating sequence of strata of limestone, limestone and shale, and sandstone, aggregating about 1,300 feet in thickness. The succession in southeastern Illinois is graphically represented in section No. 1 of the chart of sections. Eastward into central Kentucky the Mississippian section undergoes various changes. The Kinderhook either disappears in central Kentucky, or is represented by the black shale of that region. In Ohio and northeastern Kentucky the Kinderhook may be represented by the Bedford shale, Berea sandstone, Sunbury shale, and, in Ulrich's opinion, the Ohio shale above any Genesee shale that may be included in the bottom in places. The Burlington and Keokuk change to shale

and sandstone, as displayed in the knobs of southern Indiana and central and eastern Kentucky. The Meramec group persists to central Kentucky with little change. Between southern Illinois and central Kentucky the Chester group changes by loss of sandstone members in its upper and lower parts, only those of the middle part persisting unchanged into Breckinridge County. The upper limestones, too, change to predominantly shaly beds, represented by the Buffalo Wallow formation of Breckinridge County and the Pennington shale of eastern Kentucky. The character of the Mississippian in Jefferson and Breckinridge counties is shown by section No. 5 of the chart. The changes just outlined are illustrated in the chart of sections accompanying the author's report on the Mississippian formations of western Kentucky.[3] On the northeast the Mississippian of Kentucky passes into Ohio, in which state the series has long been studied, and a classification and names different from those of the Mississippi Valley have long been in use. In Ohio the Mississippian has been divided into the Waverly group below and the Maxville limestone above. According to Ohio usage the Waverly group comprises, from below upwards, the Bedford shale (which succeeds the black Ohio shale), Berea sandstone, Sunbury (black) shale, Cuyahoga formation, Black Hand formation, and Logan formation. The Maxville limestone lies between the Logan formation and the "Coal Measures." The Bedford and Berea seem to fall within the Kinderhook group, although some authors correlate only the Berea with the Kinderhook. The Cuyahoga and Logan formations in the author's opinion correspond to the Fern Glen and early Burlington, while the Maxville limestone represents the Gasper oolite of the Chester group and probably also a part of the Ste. Genevieve limestone, at least in southern Ohio. The Keokuk limestone of the Osage group and the Meramec group are not represented in northeastern Kentucky or in Ohio. The proofs of these general statements of equivalency will be set forth in the succeeding detailed descriptions which form the subject of this report.

[3] Butts, Charles, The Mississippian series in western Kentucky. Kentucky Geological Survey, 1918.

Acknowledgments. In the preparation of this report the author has had the kind assistance of E. O. Ulrich of the U. S. Geological Survey, of R. S. Bassler of the United States National Museum, and of Mr. Frank Springer, and has had free access to the Museum collections and to the type material for comparison in the study of the fossil collections. For all this assistance grateful appreciation is here expressed.

"Black Shale"

Since the "Black shale" is claimed by a number of geologists,* to be mainly of Mississippian age, it is a proper subject for description and discussion here in the introduction, though it is not classified by the U. S. Geological Survey or the Kentucky Geological Survey as Mississippian.

At the outset it should be understood that in Ohio and northern Kentucky there are two black shales, the Ohio shale below, and the Sunbury shale above, the two being separated by the Bedford shale and the Berea sandstone.

Ohio Shale

Name. The name Ohio was first applied to the lower mass of black shale by Andrews[4] in 1870, under the term Ohio black slate. In 1871 Andrews used the designation Ohio black shale. In 1877 the name was modified by Shaler[5] to Ohio shale.

The name Chattanooga was applied to a thin black shale in the southern Appalachians by Hayes[6] in 1890. The Chattanooga has been found to extend into central Tennessee and Kentucky, where it is, as the writer believes and will show beyond, continuous with the Ohio shale. In 1873 the name New Albany was applied by Borden* to the black shale of Indiana, which is clearly the same as the Ohio. In this report, the name Ohio shale is used in Kentucky throughout all the area in which the outcrop of the formation is continuous with that of the black shale in Ohio, and the name Chattanooga is retained for

*Ulrich and others.

[4] Andrews, E. B., Ohio Geol. Surv. Rept. Prog. for 1869, p. 62, 1870.

[5] Shaler, N. S., Ky. Geol. Survey, New Ser., Vol. 3, pp. 169-175, 1877.

[6] Hayes, C. W., Geol. Soc. of Am. Bull., Vol. 2, p. 143, 1891. Paper read December 29, 1890.

*Borden, W. W., Indiana Geol. Survey, Fifth Ann. Rept. for 1873, pp. 150, et. seq., 1874.

Tennessee and that part of southern Kentucky in which the outcrop of the black shale is continuous with that of Tennessee. The dividing line between these two regions passes through the narrow area in Pulaski and Casey counties in which the black shale is largely covered by higher rocks. That line is ap-

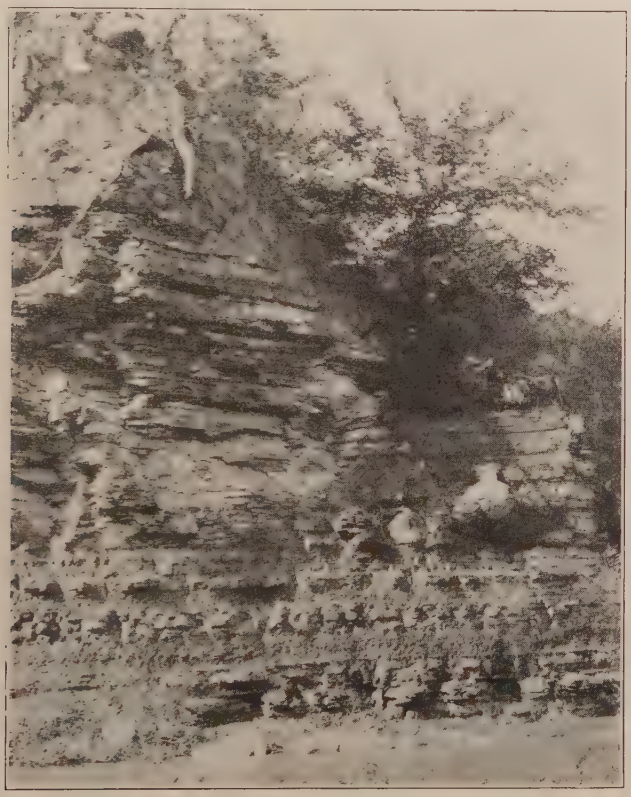


Plate 1. Ohio shale, showing Huron shale representative, with giant nodule, in lower part. Bluff on Salt Lick Creek, one-half mile southwest of Vanceburg, Ky. Looking west. Limestone of Onondaga age just below water level.

proximately the parallel of 37° 15′. At Vanceburg the lower 30 feet of the Ohio shale carries spherical nodules of limestone, of concretionary origin, the largest of which are 2½ to 3 feet in diameter. In Ohio this part has been regarded as a

distinct member of the black shale mass and given formation rank under the name Huron shale. The Huron shale representative at Vanceburg is shown in Plate 1.

Distribution. The Ohio shale can be recognized as a distinct unit as far south as Irvine, Estill County, where its thickness is reduced to about 95 feet, and where about 18 inches of indurated fossiliferous gray clay or shale representing the Bedford shale separates it from the overlying Sunbury black shale, about 3 feet thick. The situation at Irvine is exhibited in section No. 37 of the chart of sections. Southward from Irvine the Sunbury as a separate unit has not been recognized, neither have the Bedford and Berea, and it seems fairly certain that they do not extend far south of Irvine. The black shale from Irvine, or a comparatively short distance south thereof, through the counties south and west of the Bluegrass country to Louisville seems to be in the main a thinned southwestward extension of the Ohio shale, although it may include a very thin representative of the Sunbury shale in the top. The alternative to such a conclusion is that the Ohio shale continues to become thinner southwestward, and in the southern counties of Kentucky and in the vicinity of Louisville is locally represented by only a small thickness of the basal part of the black shale, that the Bedford has feathered out entirely, except perhaps locally, hereinafter to be dwelt upon, and that the Sunbury shale has thickened and makes up all, or locally the main body, of the black shale—the Chattanooga of the southern and western counties of Kentucky and of all of Tennessee and the New Albany shale of the Louisville region and Indiana. At present the first alternative, which is in accordance with common acceptance, seems to the writer the more probable. A demonstration of the truth of the matter, however, if possible, can be accomplished only by much more detailed field work.

Character. The Ohio shale is mainly a black fissile rock, but includes layers of green shale and in the bottom in places thin laminae or thin layers of sandstone and in other places thin calcareous layers. In the sections at Vanceburg about 120 feet of the formation, beginning 40 feet below the top, is noted as dark, greenish, or brownish as weathered. While there

are certainly some green shale layers in this part of the section, most of the thickness is dark or black in the fresh condition. Its character at Irvine is shown in the following section:

	Feet.
Sunbury shale	3
Bedford shale:	
6. Clay or lumpy shale, light gray with black shale parting, fossils (dist. No. 1)	1.6
Ohio shale:	
5. Shale, black	78
4. Shale, alternating green and black layers 1 foot thick	7
3. Shale, black; *Schizobolus truncatus*	4
2. Shale, black and hard with dark, probably calcareous and siliceous layers with *Lingulopora williamsana*	6
1. Shale, very soft, brown, with *Dictyonema*, annellid teeth, *Lingula* and *Orbiculoidea*	1
	100.6

Devonian limestone.

Generally throughout the state there are no such beds in the black shale as those of the lower 18 feet of the above section, but on Barren River, between Allen and Barren counties, similar beds are present. The section there is as follows:

Fort Payne chert (limestone with chert).

Chattanooga shale:	
Shale, black fissile, carrying *Lingula melie?*	33
Shale, black, highly fissile with *Schizobolus truncatus*, and thin, calcareous, sandstone laiminae	10
	43

Devonian limestone.

At Louisville the section is similar.

At New Albany, Ind., the section of the black shale is as follows:

New Providence shale.

New Albany shale:	Feet.
Shale, black, *Lingula melie* and a few other poorly preserved fossils; 1 foot green shale near bottom	85
Shale with calcareous sandstone layers up to 1 or 2 inches thick, with fish teeth and bones and plant stems, about	5
Shale, black, conchoidal, *Schizobolus truncatus* in bottom	10
	100

The localities of the above 3 sections are the only ones out of many examined in which the lower beds with *Schizobolus* have been found by the author. It seems reasonable to think that they are absent throughout most of the state.

In the vicinity of Lebanon there is intercalated in the black shale of the prevailing black fissile character a bed of gray clay 5 feet thick, shown in Plate No. 2. This is about 15 feet above

Plate 2. Gray clay 5 feet thick in Ohio black shale, 15 feet above the bottom and 40 to 50 feet below the top. About 3 miles southeast of Lebanon. Looking northwest. This bed of considerable extent in that vicinity. There is a possibility that it represents the Bedford shale of Ohio but that has not been established.

the bottom, the entire thickness being about 60 feet. This gray clay has considerable extent in the vicinity, having been observed at two points 4 or 5 miles apart. It may be in the position of the green clay layers No. 4 of the Irvine section, and the underlying 15 feet of the Lebanon section may correspond to the 10 feet of fossiliferous beds below the green clay layers at Irvine. The clay bed may, however, represent the Bedford shale, and if so the overlying black shale is Sunbury.

Another locality where a deviation from the usual black character of this shale has been seen is at Berea, Ky., where two or three layers of green shale occur 15 or 20 feet below the

top of the black shale. These were exposed in the street leading east from the town. Still another variation is a brown friable sandstone 1 foot thick at the bottom of the Black shale and lying upon the top of the Devonian limestone. This layer of sandstone is most prominent on Barren river in Barren Co., but a thin layer of similar character at the same horizon occurs south of Lebanon and in the vicinity of Berea.

With the exception of the small proportion of sandstone and of green shale, each occurrence of which may be of no great geographical extent, the Ohio shale is a black fissile rock owing its color to the presence of carbonaceous matter.

Thickness. As already stated, the Ohio shale is nearly 300 feet thick at Vanceburg. It thins, probably at a uniform rate to 95 feet at Irvine, 70 feet at least and probably a little thicker at Berea, 45 feet on Fishing Creek west of Somerset, about 65 feet at Lebanon, 106 feet in Hart County in wells, and 120 feet at Meredith in Grayson County, (from well log). In the country south of the Fishing Creek locality the black shale is called Chattanooga. In that region the black shale is 38 feet thick on Cumberland River at Eads Landing north of Monticello; 20 feet on Meshack Creek in Monroe County, about 10 miles west of Tompkinsville; 18 feet on Long Creek, Allen County, near the state line; 20 to 25 feet in Overton County, Tenn.; 43 feet on Barren River, between Barren and Allen counties, Ky.; and 55 to 65 feet in the western part of Barren County as shown by well logs. At Louisville, where the black shale is named New Albany shale, it is 100 feet thick.

Eastward from Irvine the Ohio shale thickens. In Wolfe County it is reported in two wells as 224 and 245 feet thick; in Magoffin County it is reported from 262 to 400 feet thick; in Johnson County its thickness ranges, according to well logs, from 381 to 876 feet; and on the west face of Pine Mountain, in Letcher County, the thickness outcropping has been determined by the writer to be 800 feet and the bottom is nowhere exposed. At Big Stone Gap, Va., the black shale is about 1,100 feet thick, and at Cumberland Gap it appears to be at least 500 feet thick.

Age and Correlation. The age and correlation of the black shale is one of the unsettled questions of American geology.

The question is whether the shale is Upper Devonian or lowest Mississippian. The difficulty in reaching a satisfactory answer to the question arises from two conditions: First, the scarcity and indecisive correlative value of the fossils so far obtained from the shale, and second, the impossibility of tracing the main body of the shale into regions where its relations to rocks of known Upper Devonian or lowest Mississippian age can be seen. In the only region where such relations are decisive as to the age of the Ohio shale, namely, in eastern Ohio, its lateral contacts or its passage into the Upper Devonian is hidden by overlying rocks and cannot be seen.

Fossils. As already given in the sections, page 7, in a few known localities the lower 10 to 15 feet of the Ohio shale carries *Schizobolus truncatus*. At Irvine, in addition to *Schizobolus*, *Linguloporu williamsana*, a large *Lingula*, a *Orbiculoidea*, a *Dictyonema*, and annelid teeth are present in the lower 10 feet of the Ohio shale. At Irvine, at Rockville, Rowan county, and at Vanceburg, *Lingula melie?* occurs in the upper part of the Ohio. In the vicinity of Irvine a small Lingula, perhaps an immature *L. melie*, and two specimens of a fish scale were found in the middle of the Ohio. In southern Kentucky and northern Tennessee, where the black shale is known as the Chattanooga, *Lingula melie, Orbiculoidea,* and conodonts are common in it. Conodonts are toothed fossils, some species comb-like in form, so small that many of them are scarcely visible to the naked eye. In Ohio the Ohio shale carries fossil fishes which occur commonly in the limestone nodules of its lower part, the Huron shale. These nodules with fish remains occur also in northern Kentucky and one is shown in Plate 1 (one).

Remains of several species of plants occurring in the Ohio shale are also known. There is a fossil tree, *Callixylon newberryi*, in Kentucky and 6 other species have been collected from the nodules at the top of the black shale one-half mile west of Junction City, Ky. In Ohio another form occurs which is variously called *Calamites inornatus* and *Pseudobornia inornatus*. Finally the spore cases of plants belonging to the class of ferns, minute disk-like bodies, many of which are of an amber color, are very abundant and widespread. These are known as *Protosalvinia huronensis* or simply as sporangites.

The carbonized remains of vegetal matter give the shale its black color and it is evident from that fact that vegetation was very abundant while the black shale was being deposited. The vegetation was probably largely acquatic but may also have flourished on the low lands near the water where a large part of the dead plants, the falling leaves, the broken down parts and the pollen and the spore cases were blown or drifted into the Ohio sea and there became finally incorporated into the fine mineral sediment now forming the black shale. From what is known of the nature of such plants, it seems certain that they could live only in fresh, or at most only in very slightly salt water so that they grew only in parts of the sea occupied by fresh or nearly fresh water.

The bearing of the fossils on the determination of the age and correlation of the Ohio shale will now be briefly discussed.

Of the fossils mentioned above, except *Sporangites,* only one, *Schizobolus truncatus,* seems to be certainly known outside of the Ohio shale. *Schizobolus* occurs in the Genesee shale of New York and in its equivalents south into Virginia. The Genesee occurs near the base of the Upper Devonian section of New York. It is apparently conceded by all that the part of the Ohio (or Chattanooga) shale carrying *Schizobolus,* as hereinbefore described, is of Genesee age. It is believed by Ulrich, however, the chief advocate of the Mississippian age of the Ohio shale, that the Genesee representative in Ohio and Kentucky is confined to detached areas and is separated from the overlying part of the black shale, believed by him to be Mississippian, by a strategraphic gap or hiatus (unconformity) corresponding to the Portage and Chemung formations, which constitute the main part of the Upper Devonian of New York, and which, according to his theory, are absent in central Ohio and in Kentucky. In central Pennsylvania these formations have a combined thickness of 5,000 feet. *Lingula melie, Orbiculoidea newberryi,* and a host of species of conodonts found in the Ohio occur in even greater abundance in the overlying Sunbury shale, of acknowledged Mississippian age, and the weight of their presence is in the direction of the Mississippian age of the Ohio, except the part representing the Genesee shale, sup-

posedly small, at the bottom. The prevalence in the Chattanooga shale of the same species of conodonts as those of the Sunbury shale is one of the main points in the evidence upon which Ulrich bases his correlation of the Chattanooga with the Sunbury.

According to Ulrich (unpublished compilation) there are in the Ohio shale 29 genera of fishes represented by 58 species. Of these 11 or 13 genera are represented by one or more species in the Devonian, but only one species is common to the Ohio shale and the unquestioned Devonian. Six of the Ohio shale genera are known in the Bedford shale, Berea sandstone, or Sunbury shale, overlying the Ohio shale in Ohio, and six genera are common to the Kinderhook group, constituting the basal division of the Mississippian series of Mississippi Valley. There are apparently no species common to these various formations. The testimony of the fossil fishes, therefore, is not decisive. If the Ohio shale is of Devonian age and was laid down in water continuous with the Upper Devonian sea in eastern Ohio and western New York, it would seem that, since fishes are free swimming animals and capable of ranging far and wide, some of the 58 species of the Ohio shale would have wandered eastward into the Devonian sea and have become fossilized there. The same considerations apply to the relations of the Ohio to the Kinderhook sea of the Mississippi Valley. Such facts may reasonably be held to indicate that the Ohio sea was separate from either the Kinderhook sea on the one hand or the Upper Devonian sea on the other, but do not afford a basis for a conclusion as to whether that sea was of Kinderhook or of Upper Devonian age, or whether it may not have persisted through both Upper Devonian and Kinderhook time.

The fossil plants of the Ohio shale have been accepted as evidence of its Devonian age, but the latest investigations throw doubt upon the correctness of the identification of those plants with the Devonian forms of western New York and elsewhere.

Apparently the strongest argument for the Devonian age of the Ohio is its apparent continuity with the Middle and Upper Devonian of western New York and Pennsylvania. The Ohio shale lies between the same upper and lower limits as these De-

vonian formations. The Ohio shale passes beneath the overlying Bedford, Berea and Cuyahoga formations in central Ohio, and where eastward, as along Lake Erie in northeast Ohio and western New York, the rocks occupying the same position are exposed to view, they are unquestionably Devonian. The situation may be made clear by a homely illustration. If, in central Ohio, a tunnel should be started in the middle of the Ohio shale, say 300 feet below the Bedford shale, the formation next above the Ohio, and should be driven eastward to the meridian of Cleveland, keeping the same distance below the Bedford, it would then be in the Chagrin shale, of Upper Devonian age. The same circumstances are revealed by oil-well borings on a line, say between Columbus, Ohio, and Pittsburg, Pa. The facts are susceptible of two explanations: First, the Ohio shale continues eastward, losing its black color, into the Devonian; or, second, the Ohio thins eastward and overlaps the Devonian, which on the contrary thins westward at about the same rate as the Ohio thickens eastward. The two conceptions are illustrated by the accompanying diagrams, Fig. 1.

On the first hypothesis the Ohio is Devonian, on the second it is Mississippian. Which hypothesis is true cannot, for the reason stated on page 10, be definitely established by direct observation. It may in time be determined from deep well drilling across the critical area through the preservation of the drillings. It can then be ascertained whether the black shale overlies the Devonian along a sharply-defined line diagonal to the Devonian stratification, or whether it interfingers with the Devonian, as it must do if it is really a western black facies of the eastern gray and green shale which are the preponderating constituents of the Upper Devonian of eastern Ohio and of western New York and Pennsylvania.

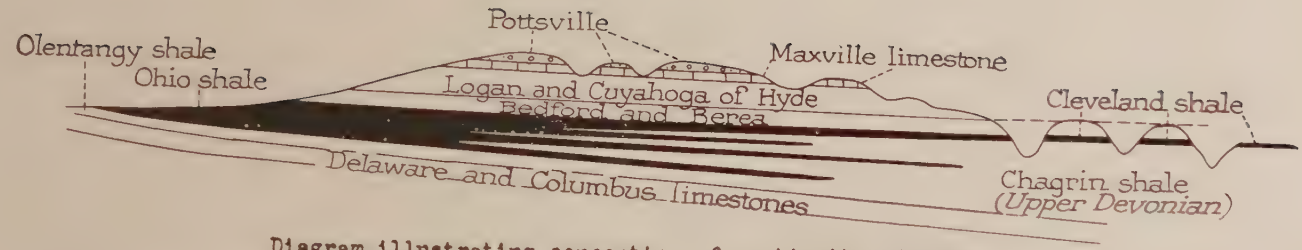


Diagram illustrating conception of continuity of Ohio shale with the Chagrin (upper Devonian) shale in eastern Ohio.

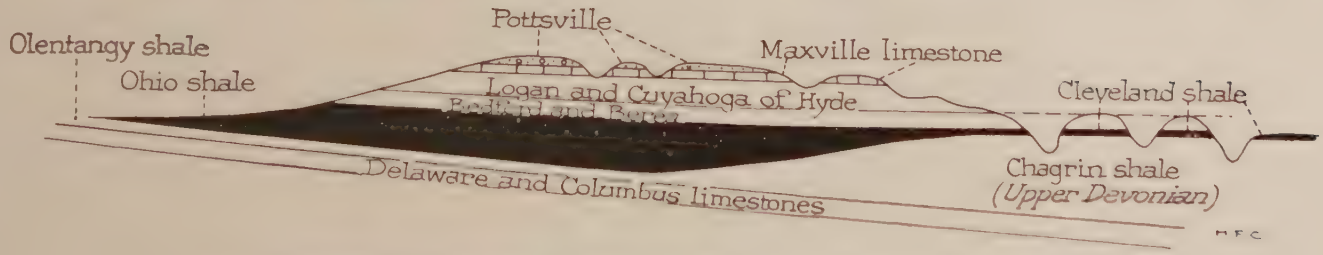


Diagram to illustrate conception of overlap of the Ohio shale upon the Chagrin (upper Devonian) shale.

Fig. 1. Ideal sections showing alternative conceptions of the age and equivalence of the Ohio shale.

CHAPTER 2.

Mississippian Formations Older Than the New Providence Group

Bedford Shale

Name. The Bedford shale was named by Newberry[7] from Bedford, in Cuyahoga County, Ohio, where the shale is 75 feet thick, is well exposed, and occupies the space between the Berea sandstone above and the top of the Cleveland shale, the upper formation of the Ohio shale group, below. The U. S. Geological Survey classifies the Bedford as Devonian or Carboniferous (Columbus Folio 1915), while the Ohio Geological Survey classifies it as Mississippian and includes it in the Waverly group as the basal formation (Geological map of Ohio 1920).

Limits. The boundary between the Bedford and the Ohio is of course very definite, but the location of the boundary between the Bedford and the overlying Berea sandstone, in Kentucky, where that formation is present, is not always certainly determinable. This is exemplified by the following two Bedford-Berea sections:

Section of the Bedford and Berea formations at Alum Rock, just south of Vanceburg, Ky.

		Feet
Sunbury shale:		
9.	Shale, black	16
Berea sandstone:		
8.	Sandstone, thick-beddd, ripple marked, aluminiferous at bottom, Plate No. 4	22
7.	Not exposed but indications of green shale mainly, with thinly laminated layers of fine-grained, ripple-marked, fucoidal, green sandstone	37
6.	Sandstone	1
5.	Sandstone and shale	5
4.	Sandstone, thick-bedded in middle	26
Bedford shale:		
3.	Not well exposed, indications of clay, thinly laminated sandstone layers, ripple-marked, and fucoidal as in No. 7	23
2.	Shale, green about	5
		119

[7] Newberry, J. S., Ohio Geol. Survey Report for 1869, p. 22, 1872.

Ohio shale:

1. Shale black.

For comparison, the following section of the Bedford and Berea at Alum Rock as made out by Morse and Foerste is quoted:

SECTION AT ALUM ROCK BY MORSE AND FOERSTE.[8]

		Ft.	In.	Ft.
5.	**Cuyahoga formation** ..... Interval covered except a thick layer of argillaceous sandstone at the top. The sandstone contains *Taonurus*. Small phosphatic nodules are found in the basal part of the interval.			39
4.	**Sunbury shale, total thickness** ..... Black, fissile, carbonaceous shales, which cannot be distinguished, lithologically, from the Ohio shale.			15½
3.	**Berea grit, total thickness**			22¼
	Thick layer of gray sandstone	2	6	
	Heavy layer of rather coarse-grained gray sandstone, the upper surface excellently ripple-marked	3		
	Medium to thick-bedded rather coarse-grained gray sandstone, beautifully ripple marked	15		
	Arenaceous shales	1		
	Layer of fairly coarse-grained gray sandstone..		9	
2.	**Bedford formation, total thickness**			95⅝
	Blue arenaceous shales and shaly sandstones.			
	Lower part slightly covered	35		
	Arenaceous shales with thin sandstone partings	7		
	Layer of thick-bedded gray sandstone	1	8	
	Arenaceous shales with two layers of sandstone	6	9	
	Heavy layer of gray sandstone, with lower surface contorted	2	4	
	Arenaceous shales with two layers of gray sandstone	6	6	
	Layer of thick-bedded buff sandstone	1	9	
	Medium-bedded gray sandstone with shaly partings	2	10	
	Arenaceous pink shales with sandstone partings	2	6	
	Covered interval	5		
	Layer of thick-bedded, buff sandstone	2		
	Practically covered interval with some argillaceous shales	22	6	

[8] Morse, W. C. and Foerste, A. F., The Waverly formations of east-central Kentucky. Jour. of Geology, Vol. 17, pp. 165-166, 1909.

1. **Ohio shale** 242
   Black fissile, carbonaceous shales. About ten feet from the top, one or two linguloid shells occur. Near the central part the shales become softer and lighter in color and resemble a similar zone in the Ohio at Columbus (Ohio). The interval (242′) is mostly exposed and extends to the level of the Chesapeake and Ohio Railroad.

Section along road on the crest of a long narrow spur known as Slate Point, beginning immediately east of Vanceburg, Ky.

Cuyahoga formation:			Feet
14.	Sandstone, even bedded (Vanceburg facies of Hyde)		80
13.	Shale, red, about	Henly shale, member of Hyde	8
12.	Sandstone, thin, greenish shaly		2
11.	Shale, soft, green, about		8
	Not exposed, includes Sunbury shale if present		22
Berea sandstone:			
10.	Sandstone, flaggy		15
9.	Not exposed		5
8.	Sandstone, thick-bedded		8
7.	Shale, green with thin layers of fine-grained, ripple-marked, fucoidal sandstone		12
6.	Not exposed. Debris of No. 7		10
5.	Sandstone, flaggy above, lower 10 feet thick-bedded, layers up to 2½ feet thick, some with uneven lower surface, lower layer makes overhanging ledge; top layers with characteristic even parallel ripple marks 2½ to 3 inches across		22
4.	Not exposed		10
3.	Sandstone, thick-bedded at bottom, has been quarried		10
Bedford shale:			
2.	Not exposed shale debris, much of it fine-grained siliceous, ripple-marked or dimpled		56
1.	Shale, soft-green, about		5
			122

Ohio shale:

Section just back of town at Buena Vista, Ohio, about 4 miles northeast of Vanceburg, Ky., Barometric measurement.

Cuyahoga formation:		Feet
	Sandstone (Buena Vista sandstone member of Cuyahoga formation), old quarry, sandstone, not now exposed.	
	Not exposed, includes Sunbury shale, if present	45

Berea sandstone:

Sandstone, thick and thin-bedded, characteristically ripple marked	15
Sandstone thick-bedded, shale partings	80
Not exposed, includes Bedford-Berea-Ohio contact, about	35
Shale, black (Ohio shale)	80
Not exposed to river's level	110

At Garrison, a few miles east of Buena Vista, the entire interval between the Sunbury and Ohio shale, estimated at about 100 feet, is, judging from all exposures, occupied by thick-bedded sandstone without shale partings even. (See Plates 5 and 6.)

Thirteen miles south of Vanceburg the following section is exposed and was examined by Morse and Foerste,[9] from whom the following section is quoted:

Section at Elk Lick Creek, 13 Miles South of Vanceburg, Ky.

	Feet
Sunbury shale:	
4. Pieces of black, fissile carbonaceous shale directly above the sandstone layers.	
Berea grit and Bedford formation:	75
3. Medium-beddied sandstones ripple-marked on the upper surfaces. Unquestionably Berea	7′ 6″
2. Covered interval, which probably contains the contact of the Bedford and Berea	67′ 6″
Ohio shale:	30
1. Black, fissile, carbonaceous shales, which extend down to the level of the highway at the spring.	

The difficulty of establishing the boundary between the Bedford and Berea in this region is apparent from the foregoing sections. In the Alum Rock section Morse and Foerste placed the boundary at the bottom of the conspicuous cliff-making upper 22 feet of sandstone, and included in the Bedford the 26 to 28 feet predominantly sandstone, some of it as thick-bedded as the upper 22 feet. The inconsistency of this procedure is evident from a study of the Slate Ridge section, barely more than a mile farther east, where the upper 82 feet of the section is predominantly ripple-marked sandstone of Berea type. East-

[9] Loc. cit., p. 168.

ward the heavy sandstone becomes still more predominant and finally occupies the entire section. The only logical procedure seems to the writer to be to place the boundary at the bottom of the heavy sandstone, and include in the Bedford only the lower 28 to 40 feet of shale or predominantly shale of the Alum Rock and Slate Ridge sections, and that is the procedure followed in this report. Just where the boundary between the Bedford and Berea is in the Elk Lick Creek section is not determinable. According to Morse and Foerste, 5 miles south of Elk Lick Creek and 18 miles south of Vanceburg the entire Bedford and Berea interval is reduced to 46 1-2 feet, and no representative of the Berea sandstone is certainly present.

Distribution. In Kentucky the Bedford shale extends from Ohio River at Vanceburg to Irvine on Kentucky River in Estill County, where it is reduced in thickness to 18 or 20 inches. It is not known south of Irvine, unless a clay bed 5 feet thick in the black shale in the vicinity of Lebanon should be the Bedford. (See p. 8, and Pl. 2.) Northeastward from Vanceburg the Bedford disappears, either thinning out or changing to a sandstone for at Garrison and along Kinniconick Creek, south of Garrison, in Lewis County, the entire interval between the Sunbury shale and Ohio shale is filled with sandstone that can only be regarded as Berea. Southeastward gray shale, or slate and "shells," in the position of the Bedford shale is reported in many oil well logs in Menifee, Morgan, Johnson, and Lawrence counties. A typical sequence is given below:

Partial Log of Well of Kentucky Block Cannel Coal Company No. 1, Morgan County, Ky.

		Feet
Shale, green	New providence shale	122
Shale, blue		84
Shale, gray		329
Shale, black (Sunbury)		24
Sandstone? (Berea?)		18
Shale, blue (Bedford?)		36
Shale, black (Ohio)		268
Shale, gray		34
Limestone to bottom of well		1
Total depth of well		1609

The succession recorded here is, with variations either actual or due to differences in the drillers' interpretation, duplicated in many well logs.

The credit for the determination of the extent and limits of the Bedford along its outcrop in Kentucky is due to Foerste and Morse[10], who in 1908 traced the Bedford southward from Vanceburg to Irvine, with the resultant discovery of its continuity and gradual thinning southward. To them is due also the important discovery of the typical Bedford fauna, well represented by a number of species at Irvine and Indian Fields.

The best exposures of the Bedford visited by the writer are at and near Rockville, 5 miles southwest of Morehead, Rowan County. (See Pl. 3.) It is partly exposed below the Alum Rock at Vanceburg and in the road ascending the crest of the long spur just east of Vanceburg. At Irvine it is too thin to be conspicuously exposed, but it can be easily uncovered on the denuded spurs at the south base of Minerva Mountain.

Character. At Vanceburg, owing to poor exposure, the details of the Bedford section could not be ascertained. It surely includes thin laminae, apparently ripple-marked, of very fine-grained, greenish sandstone, many fragments of which bearing small fucoidal markings were scattered on the surface of its outcrop. Such material occurs higher in the section, however, in shale interbedded in the Berea sandstone. The main constituent of the formation at Vanceburg appears to be a blue, indurated non-fissile clay. Five feet of soft green shale weathering to a soft green clay lies at the bottom in contact with the top of the Ohio shale. (See sec. 42 of the section chart.) At Rockville and at Bluestone Junction, less than a half of a mile east of Rockville, the Bedford is fully exposed and can be examined in detail. It is almost wholly composed of a bluish-gray, semi-indurated clay with a few rather harder thin layers, only of one of which, an inch or two thick, near the bottom, could be regarded as a very fine-grained sandstone. The exposure and character of the Bedford at this place are excellently exhibited in the photograph plate 3. At Irvine it is nearly all a hard clay, as above described. According to a report by W. S.

[10] Morse, W. C., and Foerste, A. F. Bedford fauna at Indian Fields and Irvine, Kentucky, Ohio Naturalist, Vol. 9, No. 7, pp. 515-523, May, 1909.

Plate 3. Sunbury shale, 16 feet thick, underlain by Bedford shale, 20 feet thick. Cut on Chesapeake & Ohio Railroad at Bluestone siding near Rockville, five miles southwest of Morehead. Looking west.

Peck, of Frenchburg, the Bedford in Menifee County, as revealed by the drill, is 10 feet thick and is called by the drillers the "10 foot bluish mud bench." This descriptive designation clearly indicates a rock of the character just described.

Age and Correlation. The following list of fossils is made up from material from Irvine collected and indentified by myself supplemented from Foerste's list of material collected and described by him from Irvine and Indian Fields.

List No. 1.

(b) Ambocoelia norwoodi, Foerste. Very abundant.
Camarotoechia sp.
Chonetes sp.?
(b)? Cryptonella-like brachiopod.
Lingula irvinensis, Foerste.
Orbiculoidea 2 sp.
(b) Orthotetes (Schuchertella) herricki, Foerste.
Orthotetes (Schuchertella) morsei, Foerste.
(b)? Rhipidomella sp.
(b) Cypricardella cf. C. reservatus, Hall. Figured by Herrick as Microdon bellistriatus.
(b) Macrodon irvinensis, Foerste. Same as Bedford shale form identified as M. hamiltoniae.

(b) Nuculana 2 sp. One, small, figured by Herrick as N. diversa.
Bellerophon 2 sp.
(b) Loxonema, same as figured by Herrick as L. delphicola.?
(b)? Pleurotomaria.
(b) Tropidodiscus aff. cyrtolites (Hall).

Of the forms in this list, those prefixed by a (b) are surely and those marked by (b)? are somewhat doubtfully identified with Bedford shale species of Bedford, Ohio, as listed by Girty,[11] or with Bedford species from other localities illustrated and described by Herrick.[12].

The peculiar character of most of these forms as slightly modified descendents of Middle Devonian (Hamilton) forms, together with their occurrence in the same stratigraphic sequence in both Kentucky and Ohio, leaves no doubt of the fact that the shale of Kentucky carrying this fauna is, on the ground of that circumstance alone, correctly identified with the typical Bedford shale. Besides this, however, it is probable that the Kentucky formation can be traced directly northward into Ohio into or near to the type locality. By most geologists, past and present, the Bedford shale has been accepted as the basal formation of the Mississippian in Ohio, and they have correlated it with part of the Kinderhook group, the basal division of the Mississippian of the Mississippi Valley. Girty,[13] however, influenced by the Devonian affinities of some of the Bedford fossils, has been inclined to class the Bedford as Devonian, as have Kindle, Prosser, Burroughs, Branson, and others, who have been impelled to regard the overlying Berea sandstone as the basal formation of the Mississippian because of the Devonian affinities of the Bedford fauna and also because of irregularities at the contact of the Berea upon the Bedford, which have been interpreted as evidence of extensive unconformity. A widespread unconformity at this horizon would automatically throw the Bedford into the Devonian. On the other hand, Cushing and Hyde of Cleveland have, as reported to the author by Ulrich, been adding considerably to the fossils of the Bedford, which now tend to associate it with

[11] Girty, G. H., Geologic age of the Bedford shale of Ohio. Annals of the New York Academy of Science, Vol. 22, pp. 295, 319, Nov., 1912.
[12] Herrick, C. L., Bull. Sci. Lab., Denison Univ., Vol. 4, Pl. 9.
[13] Loc. cit.

the Cuyahoga formation, of universally accepted Mississippian age. It is not likely that the Bedford will be removed from the Mississippian, in the judgment of probably the majority of geologists.

Berea Sandstone

Name. The name Berea, from Berea, Ohio, was first applied by Newberry[14] to this sandstone. He used the form Berea grit, from the fact that the sandstone in northern Ohio is an excellent abrasive and largely utilized for grindstones and whetstones.

In Ohio the Berea is the second formation of the Waverly group above the bottom, according to the Ohio classifications.

Distribution. The Berea extends south across Ohio into northern Kentucky. It is well represented at Vanceburg, Ky., at Buena Vista, in Ohio, just north of the river, and in Lewis County, Ky. It was recognized by Foerste and Morse for several miles south of Vanceburg, but on the outcrop does not extend as far south as the Chesapeake and Ohio Railroad. It seems to extend beneath several of the northeastern counties of the state, including Morgan, Johnson and Lawrence, as shown in drilling for oil. The partial log quoted on p. 19, is representative of the findings and reports of the well drillers generally in that part of the state. Farther south in eastern Kentucky, as in Floyd County, the well logs are less clear in regard to the Berea but generally do not seem to indicate its presence. A line drawn south from Vanceburg to Morgan County and thence eastward to the state line would apparently indicate the approximate limits of the Berea in the state.

The Berea is well exposed along and adjacent to Ohio River, at Vanceburg on the knob known as Alum Rock, along the river bluff in Ohio at and for a mile southwest of Buena Vista, and along the Kinniconick Creek from a mile south of Garrison on the Ohio to a mile southwest of Tannery station, where the Berea passes below creek level.

Character. The Berea is a thick-bedded, fine-grained, rather loosely cemented and soft, gray, or, on exposure, somewhat

[14] Newberry, J. S., Ohio Geol. Survey Report of Progress for 1869, pp. 21, 22, 29, 1870.

Plate 4. Berea sandstone 22 feet thick. Alum Rock, Vanceburg, Ky.

iron-stained sandstone. Its bedding and general appearance are well displayed in the photographs, plates 4, 5 and 6. A character which seems to extend through the full thickness of the formation is the remarkably even ripple marking, an example of which is exhibited in Plate 7. As there are no such ripple marks in the overlying sandstone facies of the Cuyahoga formation, they are a sure means of identifying the Berea. The Berea is without fossils.

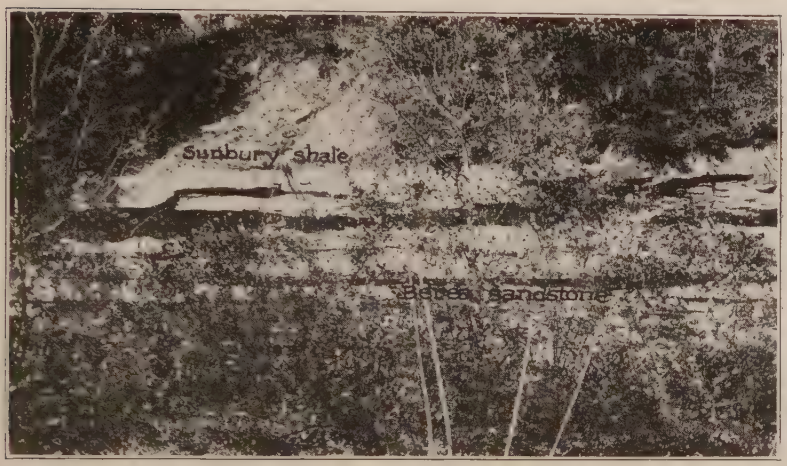


Plate 5. Berea sandstone overlain by Sunbury shale. Bank of stream near Kinniconick Branch of Chesapeake & Ohio R. R. eleven miles west of Carter and about one mile east of Tannery Station. Sunbury shale eleven feet thick, partly exposed in scar to left. Looking south.

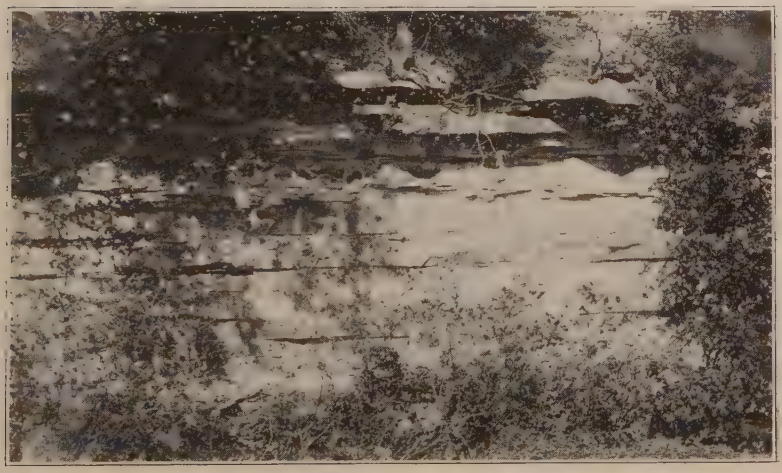


Plate 6. View of the upper fifteen feet of the Berea sandstone near Chesapeake & Ohio Railroad, Kinniconick Branch, about one mile southeast of Tannery Station, Lewis County. Looking south.

Plate 7. Surface of layer of Berea sandstone showing characteristic ripple marking prevalent in the Berea in Kentucky and southern Ohio. Ripples about four inches wide. Alum rock, Vanceburg, Ky. Looking west.

The Berea is of economic importance as a source of oil in some of the wells in eastern Kentucky. It could be used for rough masonry, although it has not been utilized to any extent for that purpose.

Age and Correlation. The Berea is accepted by all geologists as Mississippian (Kinderhook) in age. By some geologists, especially by those who are inclined to regard the Bedford and Ohio shales as Devonian, the Berea is taken as the base of the Mississippian.

Sunbury Shale.

Name. The Sunbury shale was so named by Hicks[15] in 1878.

Distribution. In Kentucky the Sunbury shale has been recognized as far south as Irvine, Estill County, where it has thinned to only 3 feet and can be separated from the Ohio shale only through the presence underneath of the thinned Bedford shale. Whether it extends south of Irvine is unknown, and unless the underlying Bedford also extends south, the Sunbury

[15] Hicks, L. E., The Waverly group in central Ohio. Am. Jour. Sci., 3d Ser., Vol. 16, pp. 216-224.

could not be satisfactorily distinguished from the Ohio shale even if it is present south of Irvine. Eastward a shale 5 to 30 feet thick in the stratigraphic position of the Sunbury, and described as black or brown, is recorded in the logs of many wells in Menifee, Morgan, Johnson and Lawrence counties, but apparently has not been noted in many wells south of these counties. This shale is probably the Sunbury, which has about the same southern boundary in the trough of the eastern Kentucky coal field as the Bedford and Berea.

Character. The Sunbury, like the Ohio, is a black, highly fissile shale, its color being due to the presence of considerable carbonaceous matter most or all of which is of plant origin.

Thickness. At Vanceburg the thickness of the Sunbury is about 16 feet; it is the same at Rockville, 5 miles southwest of Morehead, Rowan County; but at Irvine it is only 3 feet thick. About a mile southeast of Tannery, on the Kinniconick Branch of the Chesapeake and Ohio Railroad, it is about 11 feet thick. (See Plate 5.) As recorded in well logs in the counties mentioned above, it ranges from 5 to 30 feet thick.

Age and Correlation. The shale is continuously traceable to the type locality in Ohio, and there is no question of its being the Sunbury. It also carries in Kentucky the same fossils as in Ohio, the principal forms being *Lingula melie* Hall and an *Orbiculocidea* which has been usually indentified with *O. newberryi* of the Bedford shale, but which was regarded by Hall and Clarke[16] as a distinct species, named by them *O. herzeri.* The Sunbury in Ohio carries also a rich variety of the minute fossils called conodonts, and a number of species of fishes have been obtained from it. An occasional fish scale may be found in it in Kentucky. According to Ulrich the conodonts of the Sunbury seem to be characteristic of that formation, and the presence of the same species in the Chattanooga shale is one of the important items of evidence upon which his identification of the Chattanooga with the Sunbury is based.

[16] Hall, James and Clarke, J. M., Geol. Survey of the State of New York, Paleontology of New York brachiopoda, Part I, p. 126.

CHAPTER 3.

NEW PROVIDENCE GROUP

Name and Limits. The name New Providence, from New Providence, Clarke County, Ind., was introduced by Borden[17] in 1874. The formation was defined by him as including the lower 80 to 126 feet of the "Knobstone group" of southern Indiana and adjoining parts of Kentucky.

The New Providence in southern Indiana and nearby parts of Kentucky is bounded below by the New Albany shale (Ohio shale) and above by the Kenwood sandstone of early Keokuk age, giving it very definite upper and lower limits in the general type region. The same lower limit persists throughout southern Kentucky and northeastward to Berea or Irvine, where the Sunbury shale wedges in between the New Providence and the Ohio shale. The upper limiting formation, however, the Kenwood sandstone, extends southward perhaps only to Lebanon Junction, Bullitt County, Ky. In southern and eastern Kentucky the upper boundary is some one of the higher Mississippian formations which come successively into contact with the New Providence northeastward from Marion County, Ky., to Ohio River, between Vanceburg, Ky., and Portsmouth, Ohio.

The New Providence holds its character as a homogeneous unit, although increasing in thickness, from southern Indiana to the vicinity of Lebanon, Ky., where a sandstone is present near the middle. (See section No. 24 of chart and Plate 8.) From Lebanon eastward and northeastward, via Junction City, Brodhead, Irvine, and Morehead, to Ohio River, this sandstone increases in thickness and make up more or less of the upper half of the New Providence (which, in the northeastern counties is four times the thickness of the entire formation in southern Indiana), while the lower half maintains more nearly the lithologic facies of the New Providence at its type locality. The New Providence thus in its northeastern development becomes a group, being separable into two distinct lithologic divisions, which in

[17] Borden, W. W., Ind. Dept. Geol. & Nat. Res., Fifth Ann. Rept., p. 161, 1874.

Plate 8. Knob about two miles southeast of Lebanon, Marion County, capped by shelly sandstone. Represents southwestern edge of Logan sandstone of Ohio. Slumped typical New Providence shale below sandstone, 140 feet thick. Black shale at base. Looking southeast.

Ohio are recognized as of formational rank. These two divisions correspond to the Cuyahoga formation of Hyde below and the Logan formation of Hyde[18] above, each with subordinate members.

For the convenience of general treatment, under a single head, of these equivalent facies of rocks characterized from top to bottom by the New Providence fauna, and apparently included within the same time and stratigraphic limits, the name is here modified to New Providence group.

Distribution. The New Providence rocks extend from Jefferson County, Ky., southward to the escarpment known as Muldraugh's Hill, facing the Bluegrass region. Along this escarpment they outcrop in a broad belt around the Bluegrass country to Ohio River. From Muldraugh's Hill southward they extend beneath the cover of younger rocks and are probably present beneath most of southern-central Kentucky nearly

[18] Hyde, J. E., Jour. Geol., Vol. 23, pp. 657-682, 757-779, 1915.

to the state line. There are areas, though, where the New Providence is known to be absent, as along Barren River, between Barren and Allen counties, and the head of Marrowbone Creek, in Cumberland County. In southern Allen County, however, to the south of Petrolia, a small area is known in outcrop, but its geographic extent beneath the overlying rocks is not known. It is generally not present in northern Tennessee, as in Overton County, although there are outliers, one of which is known on Roaring River in Overton County, about 2 miles east of the Jackson-Overton County line. In eastern Kentucky the New Providence outcrops along the western face of Pine Mountain

Plate 9. View of Minerva Mountain, Irvine, Ky. Looking east. Slopes occupied by New Providence; summit capped by basal yellow layers of St. Louis limestone. Foreground on Ohio shale. Typical knob of the Knobs region of Kentucky.

from the Breaks of Sandy to Jellico, Tenn., and it also outcrops along the east face of the Cumberland escarpment from Cumberland Gap on the south as far north as Russell County, Va., where its outcrop is faulted out. In this eastern region the New Providence equivalent is represented in the Grainger shale. It certainly underlies the entire area of the eastern coal fields of Kentucky, as proven by hundreds of oil-well borings. The top 20 feet or so of the shale at Pineville, Bell county, where it is overlain by the St. Louis limestone, is shown in Plate 55.

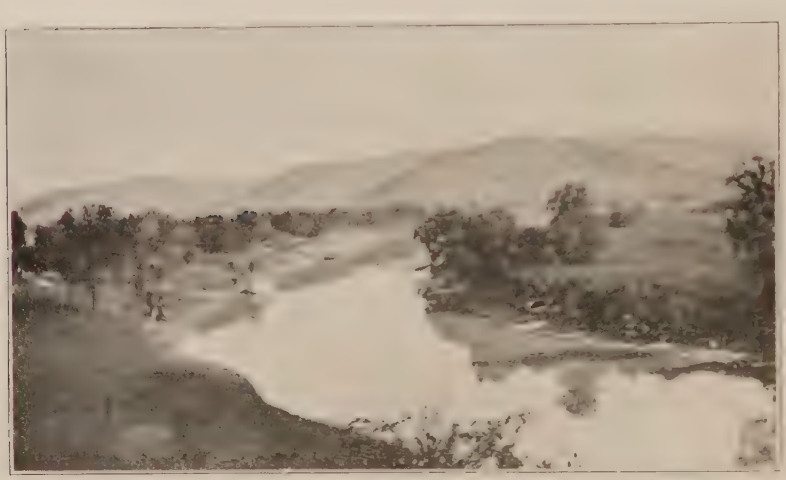


Plate 10. View looking east from Irvine, Ky. River flats about coincident with the "Corniferous" limestone of Onandaga age and with the Ohio shale in the distance. Escarpment on New Providence group. (Cuyahoga and Logan formations of Hyde). Gasper oolite and Ste. Genevieve at brow overlain by the Pottsville. Escarpment is the N. E. continuation of Muldraugh's Hill.

Most of the knobs of the knob region of Kentucky are carved out of the New Providence, and it forms the face of Muldraugh "Hill" or equivalent escarpment facing west toward the Bluegrass region. One of the knobs is illustrated in Plate 9 and the west-facing escarpment at Irvine is shown in Plate 10.

Character. The New Providence has considerable diversity of lithologic character in different areas of its geographic extent. In its type region it is usually a soft green shale which weathers to a green clay. Its weathered aspect is perfectly displayed in the washes one-half mile west of Junction City, Boyle County. This exposure is in the immediate vicinity of Linietta Springs, from which Foerste[12] gave, provisionally, the name "Linietta clay" to those beds, before their identity with the New Providence was determined. In some localities this facies of the New Providence includes thin layers of limestone composed almost entirely of crinoid plates. At such places fossils are usually abundant; from such the greater part of the known New Providence fauna has been collected. Buttonmould Knob,

[12] Foerste, A. F., Ky. Geol. Survey Bull. 5, pp. 143-178, 1905.

Plate 11. View of denuded area of New Providence shale about one-half mile west of Junction City, Ky. Looking east. Black shale and phosphate nodules containing fossil wood, crustacean remains, and *Lingula*, in level space in foreground. The surface weathers to a green clay.

Plate 12. Same subject and locality as in Plate 11. Looking [illegible] to top of knob shown in Plate 11. The exhibition of the New Providence and its characteristic vegetation, at [illegible] locality of the view shown. The Logan sandstone comes in at the top of the escarpment shown in the distance.

12 miles south of Louisville, is the most prolific and famous of these localities. Here the limestone layers extend through most of the lower half of the formation which is 150 feet thick. The north end and west side of Kenwood Hill, 5 miles south of Louisville, is another locality. There the limestone layers occupy a thiner zone near the middle of the formation. Another is on the east side of Fishing Creek, on the Jamestown road, 5 miles west of Somerset. Still another is a mile south of Petrolia, Allen County. Here the limestone is thicker and notably cross-bedded. (See Plate 13) The conditions at Buttonmould

Plate 13. Local irregularity in bedding in the New Providence shale. Louisville & Nashville Railroad about 1 mile south of Petrolia, Allen County. Looking southeast.

Knob and on Fishing Creek are shown in Nos. 7 and 21 of the Chart of sections.

A notable feature of these limestone deposits is their small geographic extent. Exposures of the same horizon within a mile or two of Buttonmould Knob reveal the entire absence of such limestone layers. Near the south end of Kenwood Hill, one-half mile distant from the point on the north end where the prolific fossiliferous limestone is present, not a trace of the limestone is to be seen in a complete exposure of the full thickness of the

New Providence. Another notable feature of this soft shale facies of the New Providence is the abundant and widely prevalent nodules composed of carbonate of lime and iron. In freshly-made exposures these preserve their form as nodules projecting from the clay or shale, but on weathered surfaces they commonly exfoliate and break up into thin, shelly, ferruginous curving chips, which strew the surface of the exposure.

The predominant soft green shale facies of the New Providence extends throughout the south-central counties as far east perhaps as Rockcastle County, as shown in section No. 29 of the section chart.

In the vicinity of Lebanon, Marion County, a sandstone is introduced into the midst of the New Providence, by which its homongeneous character prevailing westward and southward is broken up. The sandstone is about 15 feet thick, and is underlain by 141 feet and overlain by 102 feet of typical New Providence shale. (See section No. 24 of the section chart and Plate 8.) The sandstone is more or less shelly and is fossiliferous. A fossil of especial significance is *Taonurus caudi galli* (See Pl. 23), which has not been seen by the writer west or south of Lebanon, but which is increasingly common in and entirely confined to and characteristic of the sandy facies of the New Providence northeastward to Ohio and eastward to Virginia.

Eastward from Lebanon the sandstone thickens, and in the vicinity of Junction City, as shown in section No. 28 of section chart, is at least 75 feet thick to the top of the highest knob. Here the sandstone is underlain by shale typical of the New Providence, as exhibited in Plates 11 and 12. Neither its top nor the top of the New Providence is reached, so the full thickness of the sandstone is not known, nor is it known whether it is overlain by typical New Providence shale, as in the vicinity of Lebanon. Farther east, in the section from about 2 miles west of Brodhead to Brodhead, (section No. 29 of section chart), the lower 135 feet of the New Providence includes a notable amount of sandstone or sandy layers, the top 25 feet of the 135 feet being a shelly sandstone full of Taonurus. Above this is 50 feet of typical New Providence green clay shale. This is succeeded by 40 feet of slightly sandy, moderately stiff shale with abundant iron nodules. The upper

100 feet includes a large proportion of shelly sandstone. These upper beds with shelly sandstone probably are equivalent to the sandstone at Lebanon and Junction City, but the lower sandstone beds seem to have no counterpart elsewhere in the New Providence except in Lewis County, as described farther on in this report. From about the latitude of Berea northward to the part of Lewis County referred to in the last sentence, the shale and the sandstone facies of the New Providence are clearly separated near the middle of the formation, the lower part of which is predominantly shale approximating the typical New Providence in character, and the upper part is predominantly

Plate 14. View of bluff near Owsley Branch about 7 miles east of Berea, showing the transition of Cuyahoga shale into the Logan sandstone of Hyde. Looking east.

shelly sandstone full of *Taonurus*. The general character, limits, and relative thickness of these two general components of the New Providence of this part of Kentucky are fully illustrated by sections Nos. 24 to 28 and 33 to 44 of the chart of sections. The transition between these two components of the New Providence group is illustrated by Plate 14.

Cuyahoga and Logan Formations of Hyde.

General Character. The lower subdivision of the New Providence group corresponds to the Cuyahoga formation of Hyde and the upper subdivision to the Logan formation of

Hyde's classification of the Ohio rocks, and it will be possible to discriminate and map these two units in Kentucky, at least as far south as the latitude of Berea. In Lewis County, as intimated on p. 37, the lower subdivision (Cuyahoga of Hyde) of the New Providence takes on a sandstone facies, as shown in secs. 42 and 43 of the section chart. The sandstone, however, is quite different from that of the upper subdivision (Logan of Hyde.) The lower sandstone is more firmly cemented and makes coherent layers which do not break down into fragments on weathering. The layers are evenly bedded and uniform in thickness, as shown in Plate 15. This sandstone facies has been

Plate 15. "Vanceburg facies" of the Cuyahoga. The tendency to the even bedding so completely attained by the Buena Vista member shown in Plate 18 is apparent. These layers are probably about 100 feet above the bottom of the Cuyahoga. Kinniconick Branch of Chesapeake & Ohio R. R., nine miles west of Carter. Looking north.

called the "Vanceburg sandstone facies" by Hyde,[20] because well-developed at Vanceburg, Ky. It is known to extend across Lewis County and is well developed and displayed along the Kinniconick Branch of the Chesapeake & Ohio Railroad from about 1 mile southeast of Tannery to the vicinity of Ruggles, near which station lies the boundary between the two subdivisions of the New Providence. The north-south extent of this

[20] Hyde, J. E., Stratigraphy of the Waverly formation of southern and central Ohio. Jour. Geol., Vol. 23, pp. 665-682, 1915.

sandstone facies, however, has not been determined, but it is known that it does not extend as far south as Morehead nor as far north as Portsmouth. At Morehead thin even layers of sandstone in shale extending 50 feet or so above the Buena Vista sandstone member, described below, is the beginning of this sandstone facies. Within the lower 50 feet of the New Providence from Stanton to Ohio River is a sandstone member characterized by remarkably even bedding. This is the Buena Vista sandstone member of the Cuyahoga formation. The "Vanceburg facies" of Hyde is an upward extension of the Buena Vista type of sandstone.

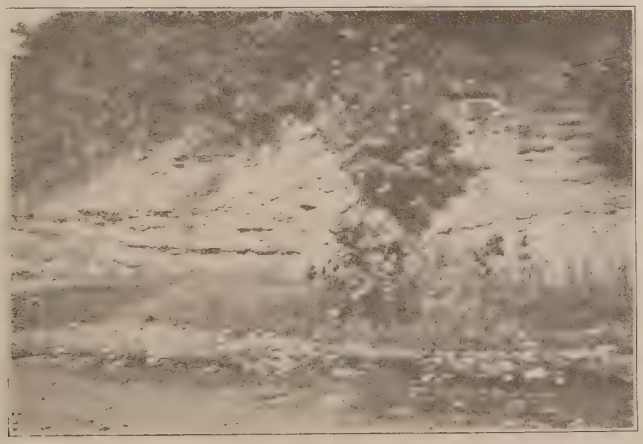


Plate 16. Exposure of Logan sandstone showing characteristic diagonally cleaving sandstone. Breaks down into small irregular plates. Rothwell, Ky. Looking northwest.

At Portsmouth the lower half of the New Providence is made up mainly of shale of its characteristic type, including, however, in the lower 50 feet or so, scattered, even layers of sandstone.

The sandstone of the upper, Logan, division of the New Providence is distinguished by its soft, incoherent, shelly character. It is affected throughout by diagonal cleavage, due to which, on weathering, it breaks down in to relatively small pieces with sharp edges and irregular surface. This peculiarity is well illustrated by the photograph plates 16 and 17. It is character-

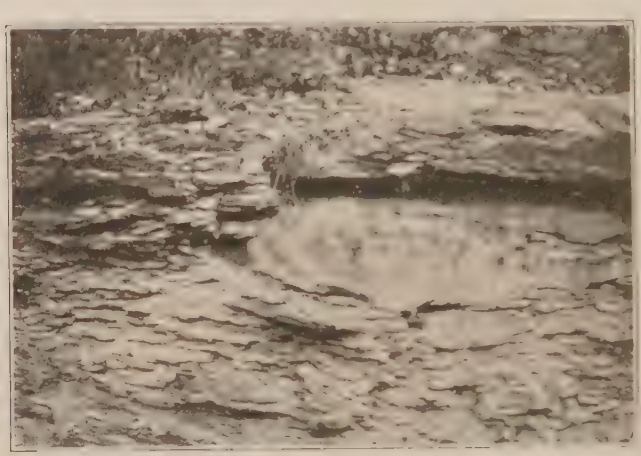


Plate 17. View of Logan sandstone showing diagonal cleavage into small pieces characteristic of the sandstone. Cut on Kinniconick Branch of Chesapeake & Ohio R. R., about 4½ miles west of Carter, Ky.

istic of this sandstone throughout its extent from Lebanon, Kentucky to Ohio. At Cumberland Gap the New Providence includes layers of a more finely shelly sandstone in shale, and farther north, as at Big Stone Gap, Va., and Jenkins, Ky., thick and more coherent layers of sandstone occur.

The New Providence is variously described in many well logs in eastern Kentucky. Perhaps the following two logs are fairly representatives: Quoted from Jillson, Oil and Gas Resources of Ky., pp. 404 and 406.

Log No. 1. F. R. Bussey Farm, Busseyville, Lawrence Co., Ky.

	Feet
Chester, etc.:	
Big lime	100
New Providence:	
Slate and shells	215
White slate	255
Total New Providence	470
Sunbury:	
Black slate	20

Log No. 2. O'Neal Farm, near Busseyville

	Feet
Chester, etc.:	
Big lime	150

New Providence:

Sand	15
White shale	10
White sand	25
Slate and shells	300
White slate	133
Total New Providence	483

Sunbury:

Brown shale	20

A fairly full description of the New Providence as a whole having been given, it remains to describe three subdivisions of some importance. These are the Buena Vista sandstone member of the Cuyahoga formation, near the bottom, the Beaver Creek oil "sand," probably at a higher horizon in the Cuyahoga, and the Morris Mountain shaly member of the Logan formation at the top of the New Providence.

Buena Vista Sandstone Member. This member was named from Buena Vista, Ohio, a town on Ohio River between Vanceburg and Garrison, Ky. At that place the sandstone was formerly quarried for use in Cincinnati and elsewhere. The Buena Vista is a remarkably even-bedded rock, of very uniform grain, of a pleasing bluish gray color, of medium hardness. It is a very free working stone and easily dressed or sawed to required dimensions. The layers, too, are separated, at least where the writer has examined the stone, by shale partings which facilities quarrying. (See Plate 18.) The bottom layer of the Buena Vista is known as the "city ledge," supposedly on account of the fact that this layer was most extensively quarried at Buena Vista for use in Cincinnati. The Buena Vista is separated from the Sunbury shale by from 5 to 20 feet of shale, usually of soft, green, marly character, like the typical New Providence, but in Lewis County, near Tannery station on the Chesapeake & Ohio Railroad, some red shale occurs. This shale below the Buena Vista has been called by Hyde[21] the Henley shale member of the Cuyahoga.

[21] Loc. cit.

Plate 18. Buena Vista sandstone member of Cuyahoga in Bluestone quarry at Rockville on the Chesapeake & Ohio Railroad, 5 miles southwest of Morehead. Looking east.

The Buena Vista, probably the "city ledge," makes its southern appearance in the New Providence in the vicinity of Stanton, Powell county, about 2 miles north of which it was observed. It is there separated from the Sunbury by about 5 feet of shale. Northward the Beuna Vista member thickens, it is supposed gradually, by the introduction of successively higher layers, until at Bluestone quarry at Rockville, 5 miles southwest of Morehead, it is 18 feet 5 inches thick. Below is a detailed section:

Section of the Buena Vista Sandstone Member at Bluestone Quarry, Near Rockville, 5 Miles Southwest of Morehead, Rowan Co. This Section is Shown in Plate 18.

Top of spur	Feet	Inches
Soil	4	
Sandstone		8
Shale	3	
Sandstone		4
Shale	5	
Sandstone	1	
Shale	7	
	21	

Buena Vista sandstone member:		
Sandstone, top layer of quarry rock		11
Shale		2
Sandstone		10½
Shale		2
Sandstone		10
Shale		10
Sandstone	1	4
Shale		1
Sandstone		9
Shale		1
Sandstone	1	8
Sandstone red		3
Shale marly green		3
Sandstone red		2
Sandstone	1	7
Shale		5
Sandstone		7½
Shale		4½
Sandstone	1	9
Shale marly		8
Sandstone		4
Shale		3
Sandstone	1	4
Shale		2½
Sandstone ("City ledge")	2	6
Total Buena Vista member	18	5
Henley shale member of Hyde:		
Not exposed } Ten feet thick, all shale a mile	16	
Shale green } or two northeast.	3	
	19	
Sunbury shale:		
Shale black	17	
Berea sandstone	absent	
Bedford shale:		
Clay, gray, indurated	20	
Ohio shale:		
Shale, black (top 5 ft. or so exposed). Thickness unknown		

Although formerly extensively quarried for building stone at Buena Vista, Ohio, and at Tannery, in Lewis county, Ky., it is now, so far as known to the writer, quarried only in Ken-

tucky at Bluestone and at Farmers a few miles southwest of Bluestone. The rock quarried at Bluestone is mostly used for making cells in which to seal up coffins.

A specimen of a sponge, probably *Physospongia dawsoni*, was found by Prof. A. M. Miller in Lexington in sandstone of Buena Vista character from Rowan county. This fossil is known elsewhere only, at Crawfordsville, Ind., where it occurs in beds referred to the Keokuk horizon.

Beaver Creek Oil "Sand." The Beaver Creek oil "sand" is a rather massively bedded limestone, from 5 feet to 40 feet

Plate 19. Beaver Creek oil "sand" in the midst of typical New Providence shale weathering to clay. Beaver Creek road, two miles southwest of Parnell in the Monticello quadrangle, Wayne County. Base of Fort Payne about edge of woods. Looking east.

above the bottom of the New Providence in Wayne County. It was named from Beaver Creek, on which it outcrops 2 miles southwest of Parnell and about 7 miles west of Monticello. This stratum is of especial importance as the oil reservoir of the Wayne County oil fields.

Where outcropping 1 3-4 miles southwest of Parnell it is 30 feet above the top of the black Chattanooga shale, the intervening rock being soft green shale, typical of the New Providence. It is overlain by about 60 feet of similar shale with thin fossiliferous limestone layers, from which a considerable

New Providence fauna has been collected. Its position in the New Providence shale is shown in Plate 19. The fossils are listed in list No. 6 beyond.

The distance of the Beaver Creek "sand" above the Chattanooga shale is not constant. About one mile southwest of its outcrop on Beaver Creek, just described, it is only 5 feet above the Chattanooga, the intervening rock being soft green shale. The immediately overlying beds, too, are very different, being mostly unfossiliferous limestone. This same variation in the position of the Beaver Creek "sand" relative to the black shale

Plate 20. Nearer view of Beaver Creek oil "sand" showing quartz that apparently formed in cavities in the limestone. Same locality as No. 19.

has been demonstrated by drilling throughout the oil fields of Wayne County. (See sections 15, 16 and 18 of the section chart.)

The geographic extent of the Beaver Creek "sand" has not been determined, but it is known beneath a large part of Wayne County.

Where outcropping the Beaver Creek "sand" is a rather dense, bluish limestone, weathering yellow or brown owing to the presence of considerable iron. In places it has inclusions of drusy or cavernous quartz several inches in diameter. (See Plate 20.) Wherever the limestone has been found to be oil-

bearing it is cavernous or porous, a condition that doubtless accounts for the presence of the oil, which presumably was derived from the underlying petroliferous black shale.

Where exposed on Beaver Creek it is about 6 feet thick. On Cumberland River north of Monticello it is 4 feet thick. In the oil wells throughout Wayne County, as reported by

Plate 21. Deep cut on Kiniconick Branch, Chesapeake & Ohio R. R., four miles west of Carter, Carter County. Looking west. Morris Mountain member of the Logan formation, 40 feet thick, overlain by Ste. Genevieve limestone.

Munn,[22] it has been found to range from 1 to 25 feet thick, the prevailing range being about 8 to 18 feet. The Beaver Creek "sand" is sparingly fossiliferous. (See list No. 6.)

Morris Mountain Shaly Member of the Logan Formation. The Morris Mountain shaly member is here named from Morris

[22] Munn, M. G., Oil fields of Wayne County, Ky. U. S. Geol. Survey Bull. No. 579.

Mountain, about 4 miles north of Stanton, Powell County, Ky., in the Beattyville quadrangle. It is composed mostly of shale, but includes subordinate amounts of sandstone and limestone or calcareous and fossiliferous layers. At Carter, Carter County, and at Deep Cut, 4 miles west of Carter, it has a bed of red shale at the top. Its general character is well displayed at Deep Cut, and Plate 21 is a photograph of this exposure. It is the topmost member of the Logan formation in eastern Kentucky. On Morris Mountain it is overlain by the St. Louis limestone and underlain by shelly sandstone of the Logan formation. Along most of its outcrop it varies in thickness from 40 to 100 feet, the prevailing thickness being about 50 to 60 feet. At Morehead it is only 15 feet thick. It is known in outcrop all the way from the latitude of Berea to that of Carter, in Carter County. Being a rather soft bed, it has yielded a soil free from stones and also has been so enriched by the wash from the overlying limestone that its area, a narrow belt extending along the steep hillsides, is extensively cleared and cultivated. This fact is well exhibited on Morris Mountain as shown in Plate 22.

The Morris Mountain member is probably the same as the Rushville group of Andrews in Ohio, but proof of this correlation is lacking. The greatest importance geologically of this member, however, is the fact that it carries the New Providence fauna from Berea to well across Lewis County, and doubtless includes the horizon as it does a large representation of the New Providence fauna of Kings Mountain. (See List No. 3.) This fact, combined with its physical continuity from a region where the New Providence is only about 300 feet thick to one in which it is 600 feet thick, proves conclusively the New Providence age of the full section between the Sunbury shale and the Maxville limestone of Ohio and northeast Kentucky, unless, as possible but not known, there are beds in the lower part of the section in northeast Kentucky older than typical New Providence.

Thickness of New Providence Group. In Jefferson County, Ky., the New Providence is 150 to 160 feet thick. It seems to hold this thickness south to Lebanon Junction and southeast to Fishing Creek, west of Somerset. On Beaver Creek, in Wayne County, its thickness is about 100 feet. On Meshack Creek, in

Plate 22. View of Morris Mountain, four miles north of Stanton, Ky. Looking north. Gasper oolite and Ste. Genevieve at top. Cleared and cultivated space on Morris Mountain member of Logan formation. Wooded slope on Logan and Cuyahoga formations. In center, and on left, top of Logan sandstone shows in woods below Morris Mountain member.

Monroe County, it is 60 feet thick. In the vicinity of Lebanon, Marion County, it is 258 feet thick. At Kings Mountain, in Lincoln County, it is about 300 feet thick, and at Brodhead it is practically the same. In the knobs east of Berea it is 400 feet thick and increases northward to a thickness of 600 feet in Lewis County. At Cumberland Gap, Va., it is about 300 feet, and at Jenkins, Letcher County, it is about 400 feet thick. Beneath the eastern Kentucky coal field the thickness of the New Providence is given in the oil-well logs in various counties as follows: Clay, 600 feet; Floyd, 400 to 450; Johnson, 365-445; Lawrence, 365-445; Knox, 300 to 350; Martin, 484; Menifee, nearly 600; Morgan, 456-535; Pike, 430; Wolfe, 500.* An eastward thinning of the New Providence is revealed by these figures in agreement with the results of observations on the outcrop on the western escarpment of Pine Mountain and on the Cumberland escarpment in Virginia from Cumberland Gap to Russell County, Va. In general the maximum rate of thickening of the New Providence is in a northeast direction from southern Indiana. It thickens at a smaller rate eastward. The increase is coincident with the increase in arenaceous matter. The northeastward increase in thickness and in proportion of arenaceous sediment continues into central Pennsylvania, where the equivalent Pocono formation is, in Broad Top Mountain, 1400 feet thick and predominantly sandstone.

Economic Products

The building stone of the Buena Vista member has already been described. In the vicinity of Louisville the clay shale of the New Providence, mixed with some more arenaceous layers, is utilized for brick. The brick, however, are subject to developing a white coating on weathering due to the efflorescene of soluble sulphates such as sodium or potassium sulphate from the soda and potash in the shale, of which analyses show about 1 per cent. of the former and nearly 5 per cent. of the latter.

Another product of even greater importance is petroleum. The Beaver Creek oil "sand" of Wayne County has already been described. In eastern Kentucky the Big Injun and Wier

*Jillson, W. R., Oil and Gas Resources of Ky. Ky. Geol. Survey, Series V., Bull. I., 1919.

sands are in the New Providence. In West Virginia and southwestern Pennsylvania the Big Injun sand has been one of the most productive oil reservoirs of the eastern United States.

Age and Correlation.

By the following lists of fossils it is proven that the New Providence shale, and with it the equivalent Cuyahoga and Logan formations of Ohio, is of the age of the Fern Glen formation of Missouri and southern Illinois or at the most that the New Providence does not include beds higher than lower Burlington.

This correlation is not a discovery of or original with the present author, but has been maintained by Ulrich, as is evidenced by many annotated labels accompanying the collections in the U. S. National Museum. Weller has expressed the same view. (Bull. G. S. A., 1910.) It is probable though that the lower Burlington is also represented in the New Providence, as attested by such forms as *Productus burlingtonensis* and *Spirifera?* The present author's main contribution to the correlation of the New Providence is the proving that it is the equivalent of the rocks in Ohio lying between the Sunbury shale below and the Maxville limestone above, and as the equivalence of those formations with the Pocono formation of Pennsylvania is reasonably well supported by several lines of evidence, it follows that the Pocono of Pennsylvania, Maryland, Virginia and West Virginia, including the Big Injun oil sand, is also of the age of the New Providence and Fern Glen, and probably of the lower Burlington. The Fern Glen has been classed by Weller[23] as Kinderhook, but Ulrich[24] includes it in the Osage group as the basal formation, and Girty[25] seems inclined to the same view. From the Pocono on the east to the Fern Glen and lower Burlington on the west there seems clearly to be a continuous delta-like body of sediment diminishing rather uniformly in thickness and undergoing a change of facies through distribution of finer and finer sediment with increasing distance from

[23] Weller, Stuart, Mississippian brachiopoda Mon. I, Illinois State Geol. Survey, p. 15, 1914.
[24] Ulrich, E. O., Revision of the Paleozoic systems. Bull. Geol. Soc. Am. Correlation chart of Mississippian series, 1911.
[25] Butts, Chas., Geology of Jefferson County, Ky. Ky. Geol. Survey Rept., pp. 144-145, 1915.

the eastern shore until at the western extreme the deposition was largely limestone. It is not improbable that the upper one-third to one-half of the Pocono, consisting of sandstone and conglomerate without marine invertebrates but with plants, is a fresh water deposit, only the lower part of the formation carrying marine fossils as in Broad Top Mountain, Pa.

List No. 2 gives the fossils occurring in the typical New Providence in the vicinity of Louisville, where the fossiliferous beds do not extend above the middle of the formation and at Buttonmould Knob go down nearly to the bottom. The material of list No. 9 is from exactly the same zone 100 miles southeast of Louisville. On the other hand, list No. 3 is of material from the very top of the New Providence where it is about 300 feet thick. The substantial identity of the faunas of lists Nos. 2 and 3 is evident from a comparison of the two lists. This proves the New Providence age of the beds at Kings Mountain. The fossils of list No. 10 carry the Kings Mountain horizon to a point 30 miles still farther northeast. Here the New Providence is at least 400 feet thick. Here also the Morris Mountain shaly member of the Logan, which carries this New Providence fauna, is well-defined, and from here it can be traced continuously along its outcrop by its topography, culture, stratigraphic relations, and fossils, to Deep Cut, on the Kinniconick Branch of the Chesapeake & Ohio Railroad 4 miles west of Carter, in Carter County. Lists 11 to 14 are of fossils from this member and other collections were made but are not listed. At Deep Cut the Morris Mountain member is about 600 feet above the bottom of the New Providence.

LIST NO. 2.

Section No. 7 of Section Chart.

List of Fossils From the New Providence Shale at Kenwood Hill, 5 miles south of Louisville, and at Buttonmound Knob, 12 miles south of Louisville, Kentucky, within the Typical Region of the New Providence.

Amplexus fragilis White and St. John.
Cyathaxonia arcuata Weller.
Cyathaxonia bordeni Greene.
Cyathaxonia cynodon Rafinesque and Clifford.
Cyathaxonia parva Greene.

Favosites valmeycrensis Weller.
Monilipora crassa McCoy
Monilipora gracilis Keyes?
Monilipora longi Rowley?
Striatopora carbonaria White.
Striatopora n. sp. Same in Burlington limestone.
Trachypora 2 species, 1 species at Kings Mountain.
Triplophyllum cliffordana E. & H.
Triplophyllum? declinis Miller
Triplophyllum? wortheni Weller
Trochophyllum verneuilliana E. & H.
Actinocrinus sp.?
Agaricocrinus sp.
Amphoracrinus sp.?
Barycrinus 3 sp.
Cactocrinus sp.?
Catillocrinus tennesseae (Troost) Shumard.
Cyathocrinus 7 sp.
Eretmocrinus yandelli (Shumard).
Gilbertsocrinus cf. tenuiradiatus Hall.
Halysiocrinus perplexus (Shumard).
Megistocrinus sp.?
Mespillocrinus 2 sp.
Metichthyocrinus tiaraeformis Springer.
Orophocrinus sp.
Platycrinus, discoid form, 2 sp. Discoid forms characteristically lower Burlington.
Platycrinus elongate form, 6 sp.
Poteriocrinus sp.?
Scaphiocrinus sp.
Schizoblastus decussatus (Shumard).
Schizoblastus granulosus (Roemer).
Stemmatocrinus trautscholdi Wachsmut and Springer.
Synbathocrinus robustus Shumard.
Synbathocrinus angularis Miller and Gurley
Wachsmutocrinus spinulosus (Miller and Gurley).
Anisotrypa hexagonalis Ulrich.
Cliotrypa ramosa new gen. and sp. Ulrich. Ms.
Cystodictya americana Ulrich.
Cystodictya lineata Ulrich.
Dendrotrypa pustulosa Ulrich. Ms.
Eridotrypa protensa Ulrich. Ms.
Fenestella albida var. richfieldensis Ulrich.
Fenestella compressa Ulrich.
Fenestella compressa var. nododorsalis Ulrich.
Fenestella exserta n. sp. Ulrich. Ms.

Fenestella meekana Ulrich.
Fenestella herrickana Ulrich'
Fenestella regalis Ulrich.
Fenestella triserialis Ulrich.
Fistulipora sigillata Ulrich M.
Leioclema floreale Ulrich. Ms.
Leioclema porosum Ulrich. Ms.
Leioclema sublimatum Ulrich. Ms.
Rhombopora exigua Ulrich.
Rhombopora incrassata Ulrich.
Stenopora scabra Ulrich. Ms.
Streblotrypa major Ulrich.
Streblotrypa spiralis Ulrich.
Vinella n. sp.
Hederella sp.
Brachythyris suborbicularis (Hall).
Chonetes shumardanus De Koninck.
Chonetes shumardanus var. 1.
Chonetes shumardanus var. 2.
Chonetas shumardanus var. 3.
Delthyris novamexicana (Miller).
Orthotetes lens White?
Productus fernglenensis (Weller).
Pustula n. sp.?
Rhipidomella oweni Hall and Clarke.
Spirifer floydensis Weller.
Spirifer imbrex Hall?
Spiriferina subelliptica McChesney.
Myalina sp.?
Igoceras sp.? cf. *pabulocrinus* (Owen).
Platyceras equilaterae Hall.

LIST NO. 3.

Section No. 22 of Section Chart.

List of Fossils from Kings Mountain Tunnel, Lincoln County.

Amplexus fragilis White and St. John?
Cyathaxonia sp.?
Cyathaxonia cynodon Rafinesque and Clifford
Monilopora crassa McCoy.
Monilopora gracilis Keyes?
Monilopora longi Rowley?
Striatopora sp. like *S. carbonaria* but somewhat smaller.
Striatopora smaller than above.
Trachypora sp. No. 1. Same at Buttonmould Knob.
Triplophyllum (*Zaphrentis*) *cliffordana* (E. & H.)

Trochophyllum verneuiliana (E. & H.)
Zaphrentis, spinulose var.
Bythoporoid bryozoan. Same at Buttonmould Knob.
Cliotrypa ramosa Ulrich. Ms.
Cystodictya americana Ulrich.
Cystodictya lineata Ulrich.
Cystodictya pustulosa Ulrich.
Cytodictya cf. C. ziczac Ulrich.
Dendrotrypa pustulosa Ulrich Ms.
Evactinopora radiata Meek and Worthen.
Fenestella compressa Ulrich.
Fenestella compressa var. *nododorsalis* Ulrich.
Fenestella germana Ulrich Ms.
Fenestella multispinosa Ulrich.
Fenestella regalis Ulrich.
Fenestella near *rudis* Ulrich.
Fenestella triserialis Ulrich.
Leioclema sublimatum Ulrich Ms.
Meekopora aperta Ulrich.
Rhombopora angustata Ulrich.
Rhombopora exigua Ulrich.
Rhombopora gracilis Ulrich.
Rhombopora incrassata Ulrich
Stenopora scabra Ulrich. Ms.
Streblotrypa major Ulrich.
Streblotrypa spiralis Ulrich.
Thamiscus divaricans Ulrich.
Thamiscus polyporides Ulrich.
Thamiscus sculptilis Ulrich.
Brachythyris suborbicularis (Hall)
Chonetes shumardanus De Koninck
Cliothyridina glenparkensis Weller.
Cyrtina sp.
Delthyris novamexicana (Miller.)
Orthotetes crenistria Phillips?
Productus fernglenensis Weller.
Pustula alternata Norwood and Pratten?
Rhipidomella oweni (Hall and Clarke).
Spirifer imbrex Hall?
Spiriferella plena (Hall)?
Platyceras equilaterale Hall.

LIST NO. 4.

List of Fossils from Railroad Cut, about one mile south of Petrolia, Allen County.

Plate No. 13.

Cyathaxonia cynodon R. & C.
Cyathaxonia sp.?
Monilipora (*Cladochnus*) *gracilis* Keyes.
Triplophyllum cliffordana E. & H.
Trochopyllum verneuiliana E. & H.
Zaphrentis cannonensis Winchell
Cystodictya lineata Ulrich.
Fenestella compressa Ulrich.
Leioclema sublimatum Ulrich.
Rhombopora exigua Ulrich.
Rhombopora incrassata Ulrich.
Stenopora scabra Ulrich Ms.
Streblotrypa spiralis Ulrich.
Athyris lamellosa L'Eveille
Brachythyris suborbicularis (Hall).
Chonetes shumardanus De Koninck.
Rhipidomella oweni Hall and Clarke.
Spirifer imbrex Hall?
Igoceras cf. *pabulocrinus* (Owen.)

LIST NO. 5.

List of Fossils from Meshack Creek, Monroe County, about 10 miles east of Tompkinsville. From 50 feet of beds next above Chattanooga Shale.

Section No. 14, Section Chart.

Cyathaxonia bordeni Greene.
Monilopora crassa McCoy.
Agaricocrinus. Undescribed sp. of Burlington affinities.
Crinoid with stem plates with wide thin flanges. Same on Beaver Creek.
Stemmatocrinus trautscholdi Wachsmut and Springer
Fenestella regalis Ulrich?
Pinnatopora flexuosa Ulrich.
Rhipidomella oweni Hall and Clarke
Igoceras cf. *pabulocrinus* (Owen.)

LIST NO. 6.

List of Fossils from Beaver Creek, in road 1¾ miles southwest of Parnell, Wayne County, Ky., in Monticello Quadrangle. From 60 feet of Shale between the Beaver Creek Oil "Sand" (Limestone) below and the Base of the Fort Payne Formation above, and from the Beaver Creek "Sand" 30 feet above Chattanooga Shale, and separated therefrom by Soft Green Shale weathering to clay.

Section No. 15 of Section Chart.

Crinoid with stem plates with wide thin flanges. Same on Meshack Creek.
Monilopora crassa McCoy.
Monilopora longi (Rowley)?
Trachypora sp.? cells in range nearer together than in T. sp. No. 1 from Kenwood Hill and Kings Mt.
Triplohpyllum cliffordana (E. & H.)
Cystodictya americana Ulrich.
Cystodictya lineata Ulrich.
Fenestella compressa Ulrich.
Pinnatopora flexuosa Ulrich.
Pinnatopora vinei Ulrich.
Pinnatopora sp.
Stenopora scabra Ul. Ms.
Streblotrypa major Ulrich?
Brachythyris suborbicularis (Hall)
Spiriferina depressa Herrick.
Cypricardinia scitula Herrick?
Igoceras sp.? large.

From Beaver Creek oil "sand" (limestone).
Actinocrinus. Keokuk form.
Agaricocrinus undes sp. Burlington type.
Cystodictya americana Ulrich.
Cystodictya lineata Ulrich.
Ptilopora cylindrica Ulrich?
Ambocoelia.
Athyris lamellosa L'Eveille?
Cyrtina.
Reticularia.
Spirifer.
Spiriferina depressa Herrick?

LIST NO. 7.

List of Fossils from Beaver Creek, 1¼ miles southwest of Parnell, Wayne County, Ky., in the Monticello Quadrangle. Top of New Providence Shale here about 100 feet above the Chattanooga Shale.

Section No. 16 of Section Chart.

Cystodictya lineata Ulrich.
Fenestella albida Hall?
Fenestella compressa Ulrich?
Fenestella germana Ulrich Ms.
Fenestella herrickanna Ulrich?
Fenestella meekana Ulrich.
Fenestella near *multispinosa* Ulrich.
Fenestella regalis Ulrich.
Fenestella near *serratula* Ulrich.
Fenestella triserialis Ulrich.
Fenestella, several other species.
Pinnatopora flexuosa Ulrich.
Pinnatopora youngi Ulrich.
Polypora sp. 1.
Polypora sp. 2.
Streblotrypa spiralis Ulrich.
Chonetes sp. 1. Same on Fishing Creek.
Chonetes sp. 2. Coarser than sp. 1.
Cliothyridina sp.?
Nucleospira barrisi White?
Orthotetes lens (White)?
Productus semireticulatus Martin.
Productella concentrica Hall?
Spiriferina depressa Herrick.
Cypricardinia scitula Herrick.
Goniatites?
Phaethonides spinosus Herrick.
Ostracod like *Primitia*.

LIST NO. 8.

List of Fossils from West Bluff of Fishing Creek, about 5 miles west of Somerset, Pulaski County, Ky., on Columbia Pike. From the Top of the New Providence Shale.

Section No. 21, Section Chart.

Cystodictya lineata Ulrich.
Fenestella aperta Hall?
Fenestella germana Ulrich Ms.

Fenestella near *herrickana* Ulrich.
Fenestella meekana Ulrich.
Fenestella regalis Ulrich.
Fenestella near *serratula* Ulrich.
Meekopora aperta Ulrich.
Pinnatopora flexuosa Ulrich.
Pinnatopora youngi Ulrich.
Polypora sp.
Brachythyris suborbicularis (Hall).
Chonetes sp.? same on Beaver Creek.
Cyrtina sp.? cf. Herrick Bull., Denison Univ., Vol. 3, p. 47, pl. 8, fig 18
Delthyris novamexicana (Miller).
Nucleospira?
Orthotetes lens (White)?
Productus semireticulatus Martin?
Pseudosyrnix gigas Weller
Spirifer floydensis Weller.
Spiriferina depressa Herrick.
Aviculopecten much like *A. duplicatus* of the Chemung of western New York.
Goniophora like *G. truncata* of the Hamilton of New York.
Macrodon like *M. hamiltoniae.*
Proetus near ellipticus Meek-Worthen.

LIST NO. 9.

Columbia Pike, Pulaski Co., Ky., abandoned site of road on east side of Fishing Creek. Basal 50 feet of New Providence Shale.

Section No. 21, Section Chart.

Cyathaxonia arcuata Weller.
Cyathaxonia bordeni Greene.
Cyathaxonia cynodon Edwards and Haime.
Cyathaxonia parva Greene.
Favosites valmeyerensis Weller.
Monilipora crassa McCoy.
Monilipora gracilis (Keyes)?
Triplophyllum cliffordana (E. & H.)
Trochophyllum Verneuiliana E. & H
Rhombopora angustata Ulrich?
Rhombopora exigua Ulrich.
Rhombopora gracilis Ulrich?
Streblotrypa major Ulrich.
Streblotrypa sp.?
Brachythyris suborbicularis (Hall).
Chonetes shumardanus De Koninck. Typical.

Delthyris novamexicana (Miller).
Orthotetes lens (White)?
Productus semireticulatus Martin?
Rhipidomella oweni Hall and Clarke
Spirifer floydensis Weller.
Spiriferina depressa Herrick?
Cypricardinia scitulus Herrick?
Igoceras sp.

LIST NO. 10.

List of Fossils from about 60 feet of Beds between 40 and 100 feet below the top of the New Providence Shale. Thin, impure, Limestones in the Lower Half. Near top of Ridge, on north side, crossed by the road from Red Lick to Owsley Branch, about 8 miles east of Berea, Madison Co., Ky. Morris Mountain Shaly Member of Logan Formation.

Section No. 36, Section Chart.

Cyathaxonia arcuata Weller.
Cyathaxonia bordeni Greene.
Monilopora crassa McCoy.
Triplophyllum cliffordana (E. & H.)
Trochophyllum verneuiliana (E. & H.)
Schizoblastus aff. *sayi* Shumard.
Cystodictya lineata Ulrich.
Evactinopora radiata M. & W.
Fenestella near *serratula* Ulrich.
Fenestella regalis Ulrich.
Leioclema n. sp.?
Rhombopora angustata Ulrich.
Rhombopora exigua Ulrich.
Rhombopora gracilis Ulrich.
Streblotrypa major Ulrich.
Athyris lamellosa L'Eveille.
Camarotoechia marshallensis Winchell?
Chonetes shumardanus De Koninck.
Cyrtina n. sp.
Cyrtina sp.?
Nucleospira?
Orthotetes crenistria Phillips.
Productus semireticulatus Martin.
Productus fernglenensis Weller.
Productus, undet. small species.
Pustula atternatus Norwood and Pratten.
Reticularia cooperensis Weller?

Rhipdonella diminutiva Rowley.
Spirifer milleranus n. sp. Butts.
Spirifer imbrex Hall?
Spirifer floydensis Weller?
Spiriferella?
Spiriferina depressa Herrick.
Crenipecten cancellatus Meek.
Cypricardinia scitulus Herrick.
Igoceras sp.?
Platyceras cf. *paralius* White and Whitfield.

LIST NO. 11.

List of Fossils from Rothwell, Menifee County, about 100 feet below St. Louis Limestone.

Section No. 39, Section Chart.

Amplexus cf. *fragilis.* White and St. John.
Trochophyllum verneuilana (E. & H.)?
Zaphrentis sp.?
Cyrtina sp.?
Diclasma sp.?
Orthotetes crenistria Phillips?
Productus aff. *arcuatus* Hall. Larger, coarser ribs.
Productus burlingtonensis Hall.
Productus sampsoni Weller.
Productus small non costate sp. with concentric wrinkles like *productella.*
Spirifer milleranus n. sp. Butts.
Spirifer biplicatus Meek (Not Hall).
Spiriferina depressa Herrick.
Conularia.

LIST NO. 12.

List of Fossils from Highway about 2½ miles west of Frenchburg, Menifee County, Ky., 20 feet below St. Louis Limestone. Morris Mountain Shaly Member of Logan Formation.

Section No. 39, Section Chart.

Athyris lamellosa L'Eveille.
Camarotoechia marshallensis Winchell?
Chonetes shumardanus De Koninck.
Orthotetes crenistria Phillips.
Productus burlingtonensis Hall.
Productus near *sampsoni* Weller.
Spirifer imbrex Hall?
Spirifer milleranus n. sp. Butts.
Crenipecten sp.?
Paleoneilo sulcatina Winchell.

LIST NO. 13.

List of fossils from Carter and Olive Hill, Greenup Co., Ky., just under Ste. Genevieve limestone.

Section No. 41, Section Chart.

Calathospongia?
Palaecis?
Zaphrentis or triplophyllum.
Camarotoechia aff. *sappho* H.
Chonetes shumardanus, sulcate var. slightly coarser *costae* than type. Probably a new species.
Orthotetes crenistria Phillips?
Ptychospira sexplicata White and Whitfield?
Productus sampsoni Weller.
Reticularia sp.
Rhipidomella diminutiva Rowley?
Spirifer n. sp.=Sp. *biplicatus* Herrick not Hall.

LIST NO. 14.

List of fossils from Deep Cut on Kinniconnick Branch of Chesapeake and Ohio Railroad, 4 miles west of Carter, Carter County, Ky From within 40 feet below the bottom of the Ste. Genevieve limestone.

Morris Mountain Shaly Member of Logan Formation.

Section No. 43, Section Chart.

Athyris lamellosa L'Eveille.
Camarotoechia sp.
Chonetes shumardanus De Koninck, sulcate var.
Dielasma sp.
Leptaena.
Orthotetes crenistria Phillips?
Productus burlingtonensis Hall.
Productus near *sampsoni* Weller.
Productus concentricus Herrick?
Spirifer imbrex Hall?
Spiriferella plena Hall?

LIST NO. 15.

List of fossils from farm of John R. Lewis, one-half mile about east of Tannery Station, on Kinniconick branch of the Chesapeake and Ohio Railroad, Lewis Co., Ky., Cuyahoga Formation of Hyde, 150 feet above Sunbury shale.

Section No. 43 Section Chart.

Calathospongia redfieldi Hall?
Ptilopora sp.?
Ambocoelia sp.

Camarotocchia aff. *saphho* Hall. Common Waverly form.
Chonetes shumardanus, var. with shallow sinus in ventral valve and 5 costae to 1 mm. Probably new species.
Cyrtina sp. same as figured by Herrick, Bull. Denison University, Vol. 3, p. 47, Pl. 48, Fig. 18.
Leptana.
Orthotetes crenistria Phillips.
Productella near *P. sublaevis* Weller.
Productus arcuatus Herrick, possibly not Hall.
Productus, arcuatus type but larger and with angular instead of rounded ribs.
Productus cf. *shumardanus* Herrick.
Rhipidomella diminutiva Rowley?
Spirifer biplicatus Herrick not Hall.
Spirifer osagensis Swallow?
Spirifer striatiformis Meek.
Spiriferina depressa Herrick.
Aviculopecten sp.
Cypricardinia scitula Herrick.

Besides the fossils listed a few others should be mentioned and comments on a few new forms should be made.

A considerable collection was obtained from the top of the New Providence on a knob just northwest of Lebanon Junction, Bullitt county, Ky. This collection contains, in addition to many of the common forms, a small *Rhipidomella* probably *R. diminutiva*, a *Mesoblastus*, *Palaeacis cavernosa*, Miller, and *Ptychospira sexplicata*, White and Whitfield. From the thin sandstone near the middle of the New Providence about 2 miles southeast of Lebanon (see p. 36, and Pl. 8) a small new species of *Chonetes*, *Delthyris novamexicana* (Miller), *Productus semireticulatus*, Martin, *Spirifer floydensis*, Weller, were collected. At Sciotoville, Ohio, at water level on Ohio River, *Productus raricostatus* Herrick and *Spirifer striatiformis* occur probably in and near the base of the sandstone of the Logan formation. *Spirifer striatiformis* occurs also in Jackson County, Ky., presumably at about the same horizon. Some fine specimens from Jackson County are in the collection of the University of Kentucky and were kindly loaned to the writer by Prof. A. M. Miller for identification. Besides the specimen of *Calathospongia* of list No. 15, a good specimen was found in sandstone float in the bed of the stream just north of Morehead.

A number of Pelecypods have been collected, particularly from the sandstone facies on Minerva Mountain and Sweet Lick Knob at Irvine. Species of *Allorisma*, pectenoid shells, *Leptodesma*, and *Palaeoneilo*, hardly good enough for specific identification were collected.

One of the most common fossils, although confined to the sandstone facies of the New Providence, is *Taonurus*. (See Pl. 23.) This is present in nearly every foot of the wholly sandstone facies of the New Providence in Lewis County, from the very basal layer (the "City ledge") of the Buena Vista mem-

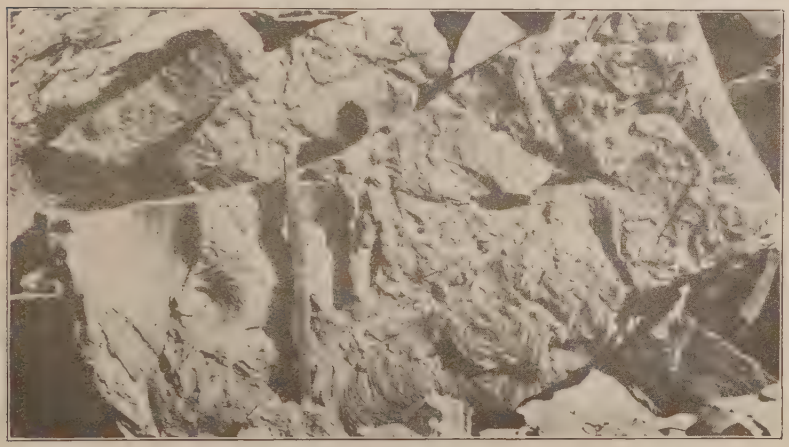


Plate 23. Block of sandstone of the Buena Vista member of the Cuyahoga formation, showing *Taonurus*. Bluestone quarry at Rockville on the Chesapeake & Ohio Railroad, five miles southwest of Morehead.

ber to the top of the Morris Mountain member in Deep Cut, on the railroad 4 miles west of Carter. It is universally present in the sandstone of the New Providence throughout Kentucky. It is believed to have been made by a big worm burrowing in the sand. It is entirely characteristic of the New Providence, the writer never having seen a specimen in the higher Mississippian formations of Kentucky or Tennessee. Another form of burrow is shown in plate 24, possibly made by the same worm as that which made the *Taonurus* markings.

Plate 24. Block of sandstone of Buena Vista member showing worm trails. Bluestone quarry at Rockville, five miles southwest of Morehead.

NOTES ON NEW AND OLD SPECIES OF SPIRIFER

Spirifer milleranus, n. sp., Butts

Plate 25, Figs. 1-3 and Plate 26, Figs. 3 and 4.

Dimensions. Seventy-five mm. long, about 100 mm. broad, and 44 mm. thick.

Pedicle valve most convex near the middle whence it curves more gently both to the front margin and nearly to the posterior margin. Curves abruptly to the lateral margins but flattens slightly near the cardinal extremities. Area of mould relatively low, about 12 mm. high at the beaks and apparently holding nearly the same width well out toward the extremities of the hinge line. Sinus shallow, with indefinite lateral boundaries. Costae coarse, 10 to 12, in 25 mm. near the front, adjacent to the sinus. So far as preserved, which is on the front two-thirds of both values, the costae do not bifuracte but increase in width toward the front. Muscle scar lozenge shaped, 1 inch long by three-fourths of an inch broad.

Brachial valve curves gently, the curvature increasing gently toward the front, apparently abruptly deflected at the beak to the margin of the very narrow area. Fold raised but slightly above the surface of the rest of the valve in the posterior two-thirds but is fairly prominent in front, not sufficiently so, however, to form a nasute extremity. The crest of the fold apparently straight from the posterior deflection to the front extremity. Costae the same as on the pedicle valve.

The surface ornentation of both valves as shown in Figs. 3 and 4, Plate 26, consists of radial striae, of which there are about 12 to 14 to each rib in the specimen figured in Fig. 3, and as many as 18 to a rib in the specimen figured in Fig. 4. As shown in Fig. 4, there are also very much finer transverse striae.

This species is apparently closely related to Spirifer logani of the Keokuk. It differs in having coarser costae, 10 to 12 in 25 mm. where Sp. logani has 14 to 16, a much more shallow sinus in the pedicle valve and a less prominent fold on the brachial valve. The shape of the muscle scar is different from that of Sp. logani. The relative proportions of the shell are about the same and the ornamentation seems to be exactly the same.

Horizon and Locality. Sandstone in Logan formation and Morris Mountain shaly member of Logan.

Hill south of Redlick Creek, 8 miles east of Berea; head of Owsley Creek; Morris Mountain 4 miles north of Stanton; Rothwell. The specimen figured as the type, Plate 25, is reported to have been obtained in Bath County. It is an internal mould posteriorly but the front part seems to be a pseudomorph of the shell in iron oxide. Its exact horizon is unknown, but it must be in the New Providence group and probably in the Logan formation. The specimen belongs to the collection of the University of Kentucky and was kindly loaned by Prof. A. M. Miller after whom it is named. A specimen of this species has recently been obtained at Dump Creek, Russell county, Virginia, from the top of the Grainger shale, which is in part of the age of the New Providence group, in beds that may represent the Logan formation.

Spirifer imbex Hall?

A common Spirifer in the New Providence group has a shell marked with strong, closely spaced, traverse lines, made by imbricating lamellae the margins of which, arching forward upon the costae give the shell a wave-marked appearance which at once attracts the attention. No perfect specimen of this species has been obtained but fragmentary material is common and widely distributed.

The species seems to be about 2 to 2 1-2 times as broad as long. The specimen shown in Fig. 2, Plate 27, is 30 mm. long and 75 mm. broad to the extremities of the mucronate extensions of the hinge. One specimen is 100 mm. broad and the pedicle valve shown in Figs. 1 and 2, Plate 26, indicates an individual of equal or even greater breadth. The thickness of the larger individuals seems to be about 25 mm.

The pedicle valve has a rather broad sinus of moderate depth and with well-defined boundaries. The area of the pedicle valve at the beak seems to be about one-sixth as high as long. It decreases in height slowly for a distance from the beak and then holds the same height for a distance, then tapers to the cardinal angles. The brachial valve has a rather high and angular fold. Both sinus and fold have from 8 to 12 costae.

The ribs number about 24 in 25 mm. Besides the transverse wavy edges of the lammellae, the surface is marked by fine radial striae and by still finer transverse striae which seem to be crowded upon the central part of each lammella.

This shell seems to be more like Spirifer imbrex than any other described species. It agrees in most respects with specimens in the National Museum from the Lake Valley limestone of New Mexico, that have been identified as Spirifer imbrex. The type of the species is a single brachial valve from the Burlington limestone of Iowa. No pedicle valve from the Burlington limestone is known. In view of the lack of material for comparison it seems best to refer this species with some doubt to Spirifer imbrex, although it may later be found to be a distinct species.

Horizon and Locality. Lower half of New Providence shale, Buttonmould Knob. Top of New Providence, Lebanon Junction, Bullitt County; and Kings Mountain, Lincoln County. Morris Mountain shaly member of the Logan formation, south of Redlick Creek 8 miles east of Berea; Frenchburg, Menifee County; and Deep Cut 4 miles west of Carter, Carter County; also top of the Grainger shale, Dump Creek, Russell County, Va.

Spirifer osagensis Swallow.

The specimen identified as *S. osagensis* collected at Tannery, Lewis County, from about 150 feet above the Sunbury shale, although not preserving the entire outline of the shell, does preserve the ornamentation perfectly, which agrees with that described by Weller as characterizing that species. This form, if really the *osagensis*, indicates a Kinderhook horizon and suggests the possibility that the beds here may be somewhat older than the base of the typical New Providence. The *Productella* near *sublaevis* and *Productus arcuatus* of the list point in the same direction.

As indicated at the beginning of this section the nearly complete equivalence of the New Providence and Fern Glen is indicated by the fossils listed. In support of this conclusion list No. 16 of identical species from the Fern Glen is given.

PLATE 25.

Spirifer milleranus, n. sp., Butts.

Figs. 1-3. Pedicle, brachial, and posterior views of a specimen which is an internal mould posteriorly but apparently a pseudomorph in iron oxide anteriorly. Slightly reduced. New Providence formation, Bath County.

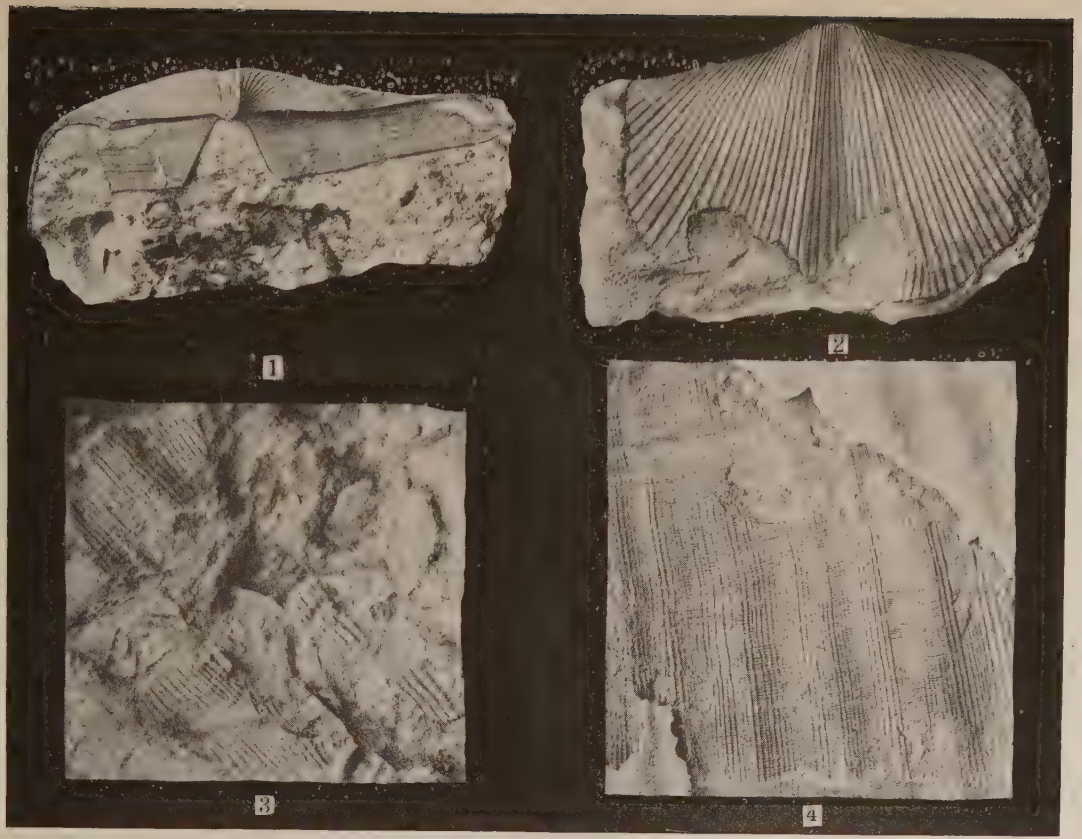


PLATE 26. Figs. 1-2. Spirifer imbrex, Hall? Pedicle and posterior views, slightly reduced. Top of New Providence, King's Mountain, Lincoln County. Figs. 3-4x5½. Spirifer milleranus, n. sp. Enlarged views showing the surface ornamentation. Fig. 3. Part of surface of brachial valve shown in Plate XXV, Fig. 4. Part of surface of another specimen. Morris Mountain shaly member of Logan formation.

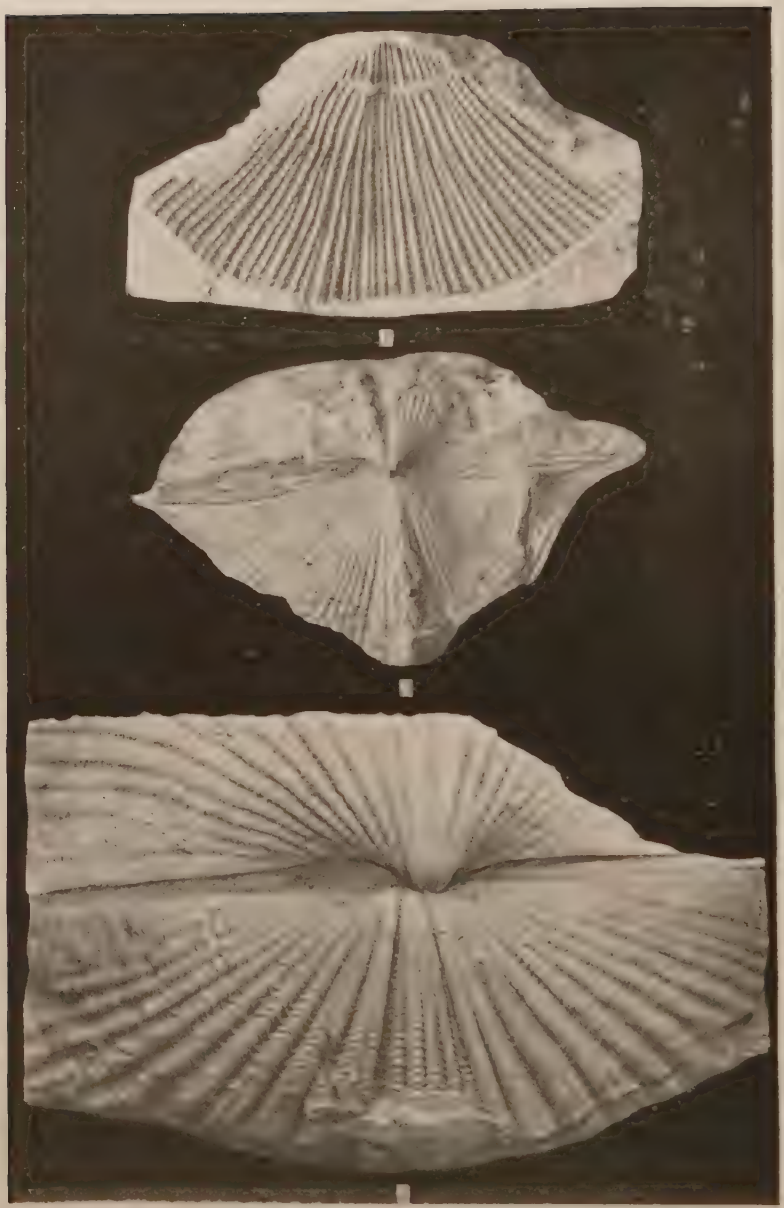


PLATE 27. Spirifer imbrex, Hall? Fig. 1 x 1¾. Enlarged view of natural mould of brachial valve showing ornamentation. Fig. 2. Brachial valve of imperfect specimen, slightly reduced. Top of New Providence, King's Mountain, Lincoln County. Fig. 3 x 3½. Enlarged posterior view of a specimen preserving the shell and ornamentation. Top of New Providence, Lebanon Junction, Fullitt County.

LIST NO. 16.

List of Fossils from the Fern Glen Formation of eastern Missouri and southern Illinois, and from contemporaneous beds in the St. Joe limestone member of Boone limestone at War Eagle, Arkansas, and elsewhere in Arkansas and Missouri, that occur also in the New Providence shale. Partly from material in the U. S. National Museum collected and identified by Ulrich and partly from Weller, Bull. G. S. A., Vol. 20, pp. 265-332, Pls. 10-15, 1909

Cladochnus (*Monilopora?*) *Americana* Weller.
Cyathaxonia arcuata Weller.
Favosites valmeyerensis Weller.
Monilopora crassa McCoy.
Trachypora sp. 2.
Triplophyllum cliffordana E. & H.
Zaphrentis (*Triplophyllum*) *wortheni* Weller.
Schizoblastus (*Pentremites*) *decussatus* Shumard.
Cysiodictya lineata Ulrich.
Cystodictya n. sp. same at Kings Mountain.
Dendrotrypa pustulosa Ulrich Ms.
Evactinopora sexradiata Meek and Worthen.
Fenestella albida Hall var. *richfieldenses* Ulrich.
Fenestella compressa var. *nododorsalis.*
Rhombopora angustata Ulrich.
Rhombopora incrassata Ulrich.
Athyris lamellosa L'Eveille.
Delthyris novamexicana (Miller).
Leptaena
Productus fernglenensis Weller.
Productus sampsoni Weller.
Ptychospira sexplicata White and Whitfield.

The list includes 22 species, all of which except *Evactinopora sexradiata,* are common to the New Providence. The genus Evactinopora, represented in the New Providence at Kings Mountain by *E. radiata,* is so rare and peculiar that any member of the genus is about as good evidence as an identical species.

Unconformity at Top of New Providence Group

The New Providence is succeeded in different areas by formations of different ages, ranging from the Fort Payne, of Keokuk age, in southern Kentucky, to the Ste. Genevieve limestone or the Pottsville formation in northern Kentucky. The nearest approach to a complete sequence is in central Kentucky,

where rocks of Keokuk age succeed the New Providence. Even here, however, there may be a break in the sequence, due to the absence of the upper part of the Burlington limestone, no evidence for the presence of which has been found in Kentucky. In localities where the New Providence is succeeded by the Pottsville, as south Portsmouth, the break is much greater, being represented by the full thickness of the Fort Payne and the Meramec and Chester groups of the Mississippian and by whatever lower part of the Pottsville may be absent. The combined thicknesses of the absent formations would amount at the least to over 2,000 feet. (See fig. 2 p. 183.)

The simplest explanation of this condition is that the absence of the formations from their place in the general stratigraphic succession is the result of dry land, or of very shallow water so that no sediments were transported to the areas where the formations are now absent, or that, during the time of the deposition of these formations elsewhere, deposition in the areas of absence was prevented by currents. Another explanation is that the absent rocks were deposited and subsequently the areas where they are now absent were elevated above sea level and the formations were removed by erosion before the formation now overlying the New Providence in any area was deposited. As a matter of fact the present conditions are probably the result of a succession of oscillations producing also minor unconformities in the mass of limestone overlying the New Providence. These conditions are much too complicated for an attempt at their detailed description to be made in this place.

CHAPTER 4.

Rocks of Keokuk Age

The rocks included under this head are so treated on account of their regional variability, as will appear from their description. In Jefferson County and the surrounding region of Kentucky they include the following units in ascending order: The Kenwood sandstone, the Rosewood shale and the Holtsclaw sandstone. In southern Kentucky they are included in the Fort Payne formation.

Limits. The bottom of the rocks of Keokuk age is usually well enough defined, since in most of their extent they lie upon quite different kinds of rock, as the green shale of the New Providence or the black Ohio shale. In places the unconformity at the base of the Keokuk rocks is manifested by a slight discordance of bedding. Such a locality is on the railroad 1 mile south of Petrolia, Allen County, where the contact of the Fort Payne on the New Providence is exposed. The slight angular unconformity is plainly shown in the photograph, Plate 28. The top of the Keokuk is in places less satisfactorily determinable. This is particularly true of the region south of Louisville. Here the writer in 1914 placed the top of the Keokuk at the top of the Holtsclaw sandstone. This horizon is marked locally by either a layer of oolite 2 feet thick or by a glauconitic green clay. Recently, however, it has been ascertained that there is in that general region south of Louisville, above the oolite and glauconite, 30 to 60 feet of limestone rather more like the Keokuk than the Warsaw and also carrying a few fossils elsewhere assigned to the Keokuk. This discovery has cast some doubt as to the correctness of the location of the boundary at the top of the Holtsclaw. However, since the presence of the oolite and glauconitic clay may indicate a slight break, and since there is a glauconitic layer of rather wide geographic extent at apparently the same stratigraphic horizon in Rockcastle, Madison, and Jackson counties, and as a thin layer of such rock serves excellently as a boundary, it has been decided to adhere to the upper limit of the Keokuk as adopted in the Jefferson County report referred to and include the doubtful beds in the War-

Plate 28. Contact of New Providence and Fort Payne formations showing a slight angular unconformity. Prof. Arthur M. Miller holds hammer on contact. Top of New Providence here limestone with partings of characteristic green shale.

saw formation. This boundary will be further discussed in the section on age and correlation and in the description of the Warsaw formation.

Distribution. The Keokuk rocks underlie all of Kentucky west of the "Knobs" region of Jefferson and Bullitt counties and south of the crest of the north facing escarpment (Muldraughs Hill), bounding the Bluegrass region on the south. In southeastern Kentucky they extend north to a limit approximately represented by a line drawn from a point a few miles north of Mount Vernon, in Rockcastle County, to a point unknown but probably only a short distance north of Cumberland Gap at the southeast corner of the state. About 5 miles northeast of Mt. Vernon the Keokuk is represented by about 2 feet of limestone between the New Providence and the Warsaw and at Cumberland Gap by 15 feet of chert between the New Providence and the Ste. Genevieve. This chert is of typical Fort Payne character. At Pineville the

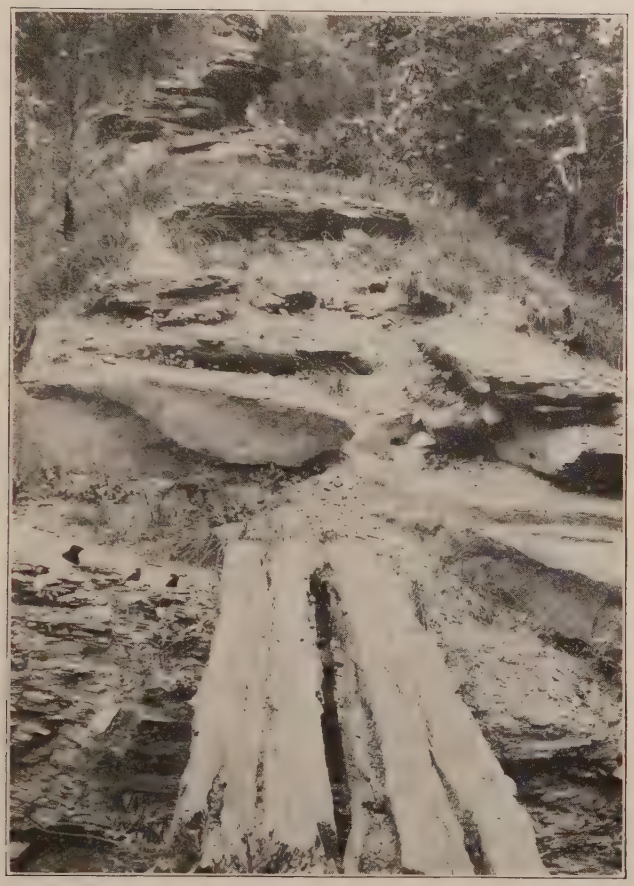


Plate 29. View of comb on Beaver Creek where closely approached by Long Run, two miles due south of Parnell in the Monticello quadrangle, Wayne County. Looking east. Shows prevailing character of Fort Payne formation in region. This is the Rosewood facies of the Fort Payne characterizing it in the "Knobstone group" of Jefferson County, Ky., and in southern Indiana. Stiff calcareous shale breaking down into chips on extreme weathering.

Keokuk is absent. Its approximate northeast limit is shown on the key map on the section chart.

Character. Throughout the part of Kentucky east of the western Kentucky coal field the Keokuk rocks are predominantly clastic, their main component being a siliceous, argillaceous, and probably slightly calcareous rock breaking down into shale on weathering. This character is well displayed in

Plate 29. In Jefferson County the rocks of Keokuk age are divisible into three formations, the Kenwood sandstone below, the Rosewood shale in the middle, and the Holtsclaw sandstone above. These formations are here briefly described.

Kenwood Sandstone.[26] The Kenwood sandstone, named from Kenwood Hill, 5 miles south of Louisville, is a hard, rather even-bedded sandstone, usually interbedded with shale. On Kenwood Hill and on Jacobs Park Hill, one mile northwest, the lower part of the Kenwood, which only is present, is thick-bedded, the layers reaching a thickness of over 2 feet. On Buttonmould Knob, 12 miles south of Louisville, it is 20 feet thick and massive; southwest of Huber, still farther south, it is rather thick-bedded but thinner as a whole; and at Lebanon Junction it has dwindled to a soft shelly sandstone hardly distinguishable from the overlying Rosewood shale. (See sections Nos. 4, 7, 8, 9, 10 of section chart.) The Kenwood is included in the Keokuk because of its lithologic character and because it carries *Products wortheni*, a Keokuk fossil. This is the only fossil found in the Kenwood, and it is very rare.

Rosewood Shale.[26] The Rosewood shale is identical in character with the shaly facies and components of the Fort Payne of southern Kentucky and middle Tennessee, already referred to and to be described. It includes a few thin layers of limestone a little distance above the middle. It is 190 feet thick.

Holtsclaw Sandstone.[26] The Holtsclaw is a soft sandstone about 20 feet thick in Jefferson County, Ky. It does not extend south of Jefferson County, and is absent in the southwest part of that county. At Borden, Clark County, Indiana, the upper 100 feet or so of the Keokuk rocks is sandstone, of which the upper 20 feet is rather massive and probably represents the Holtsclaw, while the lower 80 feet probably represents the upper part of the Rosewood shale and may be the same as the Riverside sandstone of Indiana reports. The Holtsclaw carries a fairly abundant Keokuk fauna which is listed in the report on Jefferson County cited.

Fort Payne Formation. South of Muldraugh's "Hill," in

[26] Butts, Charles, Geology of Jefferson Co., Ky. Ky. Geol. Survey, 1915.

all the counties where they are exposed, from Barren County on the west to Wayne County on the east, and in the counties of northern-middle Tennessee as far south as Overton County, the rocks of Keokuk age are predominantly a stiff shale of the Rosewood type, but include limestone of varying degrees of purity in beds of varying thickness and extent. The prevailing proportion is roughly estimated at two-thirds shale and one-third limestone. In that region the name Fort Payne formation has usually been applied to these rocks by stratigraphers, but their Keokuk age has always been recognized by paleontologists. Lithologically they are neither the same as the typical Fort Payne, which is predominantly a chert, on the outcrop at least, nor the typical Rosewood, which is all shale, nor like the typical Keokuk, which is all limestone. Having been traced by mapping nearly continuously into the typical Fort Payne, however, and there being no doubt of their approximate equivalence, the use of the name Fort Payne formation will be continued here for southern and eastern Kentucky and middle Tennessee. The name was introduced by Hayes[27] in 1890 from Fort Payne, Ala.

While generally in northern middle Tennessee and southern Kentucky the Fort Payne is nearly all shales it may change in a comparatively short distance to nearly all limestone. An example of such a change of facies is to be seen in Overton County, Tenn., in the Standingstone quadrangle, between the Dry Fork of Mill Creek west of Hilham and Roaring River at Crawford Mill, about 8 miles southeast of Hilham. On Dry Fork the Fort Payne is practically all shale; at Crawford Mill nearly the whole of the lower 140 feet is solid limestone. A photograph of this exposure is published in Bulletin 24, Part II-A of the Tennessee Geological Survey Annual Report for 1919. Another example fully as impressive is found on Beaver Creek, Wayne County, Ky., 1 to 2 miles southwest of Parnell. Here within one-half mile the lower half of the Fort Payne changes from thick-bedded, gray, coarse limestone to practically all shale. See sections 15 and 16 of section chart.

[27] Hayes, C. W., Geol. Soc. Am. Bull., Vol. 2, p. 143, 1891. Read December 29, 1890.

The shale of the Keokuk, including the Fort Payne, is dark to dark gray, or even, in a few localities, greenish in the lower part. The shale is not evenly fissile, like the Ohio shale, with thin, smooth surfaced laminae of paper-like thinness, but tends to cleave diagonally to the bedding into small, uneven surfaced, sharp-edged chips.

Judging from analyses of the Rosewood shale, the shale of the Fort Payne is high in silica and some of it carries a small percentage of calcium carbonate. Four samples of the Rosewood shale distributed through the thickness of the formation, 1 mile west of Brooks, Bullitt county, Ky., ranged in percentage of major constituents as follows: Silica 63.56 to 68.36 per cent; Alumnia 13.19 to 18.81 per cent; calcium oxide .25 to 3.10 per cent. Only one sample showed 3.10 per cent calcium oxide, equivalent to 5.53 per cent carbonate; the other three samples showed less than one per cent calcium oxide. The other constituents were water, iron oxide, sodium oxide (soda) and potassium oxide (potash). (See table of analyses, Jefferson county report by author referred to, p. 236.)

The limestone is of two kinds, one of which is thick-bedded, coarse, light or bluish gray, highly crinoidal, being a mass of crinoid stem plates; and the other fine-grained, unfossiliferous, bluish gray and medium thick-bedded. This kind of limestone is highly siliceous and doubtless the shale of the formation in many localities is derived from such rock by the solution and leaching of the limy content as the limestone weathers on the outcrop. The general appearance of this kind of limestone is shown in Plate 30, that of the coarse-grained fossiliferous limestone in Plate 31. The siliceous layers commonly become completely silicified to brittle chert on weathering. An example of such chert is shown in Plate 32. It is from such limestone that the completely chertified beds of the typical Fort Payne chert of Alabama is derived. Considerable thicknesses of such limestone, comparatively fresh, are exposed in the vicinity of Blount Springs, Ala. Such silicified limestone layers are exceedingly hard and a great hindrance to oil-well drillers, many hours, or even days, being consumed in penetrating a few feet. In some localities, as in Barren County, Ky., and Overton County, Tenn., certain layers on the

Plate 30. Siliceous limestone with shale partings typical of the Fort Payne chert. Road cut on Tompkinsville pike near Skaggs Creek about one mile south of Temple Hill, Barren County, Ky. Looking southwest. Such limestone silicifies to chert. Example shown in Plate 32.

Plate 31. Basal, coarse, gray limestone of the Fort Payne resting on New Providence shale. Columbia pike on west bluff of Fishing Creek, five to six miles west of Somerset. Looking south. Fossils of list No. 8 were collected from the New Providence shale, just beneath this limestone.

Plate 32. Typical Fort Payne chert. Columbia pike on west bluff of Fishing Creek, five to six miles west of Somerset, Ky. Looking east.

weathered outcrop have the appearance of brown sandstone. This is highly porous or spongy and is doubtless the result of the leaching of the calcium carbonate from layers more coarsely siliceous than the layers that weather to shale.

Throughout all of southern-central Kentucky and northern-middle Tennessee the beds of coarse, gray, crinoidal limestone occur at most any horizon in the Fort Payne. In Barren County, Ky., two such beds, at about 30 feet and 80 feet below the top, appear to be fairly persistent. In a few localities an unusual thickness of very coarse, massive, in some places cavernous limestone 10 to 50 feet thick makes the bottom of the Fort Payne, resting either upon the New Providence shale or, where that is absent, upon the Chattanooga shale. The thick limestone on Beaver Creek, 1¼ miles southwest of Parnell, shown in section No. 16 of the section chart, is an example of such development. Another such is on Meshack Creek, Monroe county. These developments are lenticular and of small areal extent. In Meshack Creek, a section at the edge of one of those lenses is exposed. In this section masses of the limestone are scattered on the surface of a point of a spur below its horizon, but it is not present in place in the side gullies in clearly-exposed sections from well up in the Fort Payne down to the Chattanooga. Just

across a ravine, possibly one-eighth of a mile distant, and across the main valley perhaps one-half mile distant, the massive limestone, 20 feet or more thick, outcrops as a ledge that persists for a long distance along the bluffs of the creek. This ledge is at exactly the level of the contact of the Fort Payne and New Providence in the exposed section where the massive limestone is absent between them, but the masses on the slopes below the contact show that its edge lay against the exposed beds at their contact on the point of the spur. Another locality of this limestone, but not so thick as usual, is at the head of Marrowbone Creek, in Cumberland County.

On Roaring River, Overton County, Tenn., in the Standingstone quadrangle, is an instructive section showing, by the fossils collected, the Keokuk age of this massive limestone. Beginning at Browns Ford, 5 miles south of Hilham, the Chattanooga shale is overlain by a few feet of crinoidal limestone, and the limestone is followed above by nearly unbroken shale, about 200 feet thick, of the ordinary Rosewood type. On the bluff one-half mile west of Browns Ford the limestone, there also immediately overlying the black shale, appears to be at least 40 feet thick, coarse and massive. One-half mile farther west the same limestone is 40 to 50 feet thick, but there is between it and the Chattanooga shale 25 to 40 feet of thin-bedded or laminated, partly reddish limestone interbedded with green shale, as shown in the following section:

Section of the basal (Fort Payne Beds) and the New Providence formation on Roaring River, Overton County, Tenn., 1 mile west of Browns Ford and 2 miles east of the Jackson County Line.

	Feet
Fort Payne Formation:	
Limestone, coarse, massive, crinoidal	50
New Providence formation:	
Limestone and shale, limestone thin-layered, reddish	13
Shale, green	9
Limestone in shale with bryozoa	3½
Shale, green with phosphatic nodues	1
Chattanooga:	
Shale, black	20
Ordovician:	
Limestone	

From the slope on the shale and limestone, of the New Providence, the following species of fossils were collected:

Cyathaxonia sp.?
Monilopora crassa McCoy.
Agarocrinus americanus Hall?
Alloprosallocrinus conicus Lyon.
Cattillocrinus tennesseeae Shumard.
Eretmocrinus ramulosus Hall.
Stemmatocrinus trautscholdi Wachsmuth and Springer.

The crinoids were identified by Mr. Springer, all without question except the Agaricocrinus, which, however, he felt fairly sure is the species named. The *Agarocrinus*, *Alloprosallocrinus*, and *Eretmocrinus* are all, according to Springer, strictly Keokuk forms; the other species named are as distinctly New Providence forms. It is plain, therefore, that both Keokuk and New Providence rocks are present, and that the mixture of the fossils came about through the Keokuk forms rolling down the slope upon the outcrop of the New Providence shale which yields the New Providence fossils. Since the heavy basal limestone of the Fort Payne extends to the top of the bluff, the source of the Keokuk crinoids could not have been above, so must have been in that limestone which is crowded with crinoidal remains.

The importance of this determination is that it proves the Keokuk age of the limestone under discussion, which is widely distributed in middle Tennessee and Kentucky, although it is in all cases a lenticular development and nowhere of great areal extent. Judging from the circumstances, the New Providence at this point on Roaring River is a residual body of small extent from the erosion taking place in the time represented in the unconformity at the top of the New Providence.

The farthest northeastern development of coarse limestone in the Keokuk that has been observed is in vicinity of Calvary, about 4 miles south of Lebanon, Ky. Here is a highly fossiliferous, bluish, coarse limestone, of importance because of carrying a considerable suite of characteristic Keokuk fossils, which come in immediately above shale with characteristic New Providence fossils. This limestone, however, is not so coarse, massive, or thick as that referred to on Meshack Creek or Roaring River,

Tenn. On Fishing Creek, 5 miles west of Somerset, and at Kings Mountain, in Lincoln County, the Fort Payne is predominantly limestone and chert and only about one-half as thick as the shaly facies of the formation farther west and southwest. On the Louisville & Nashville Railroad midway between Maretburg and Brodhead, Rockcastle County, about 5 feet of siliceous shale with thin, apparently slightly calcareous, nodular layers immediately overlying sandy shale with *Taonurus*, is doubtfully regarded as Fort Payne. On Town Branch, about 3 miles northeast of Mt. Vernon, and at Hummel station, about 1 mile farther northeast, about 2 feet of limestone with a few poorly preserved fossils referred to the Fort Payne, is the extreme northeastern observed representative of the Fort Payne. At Pineville, the Fort Payne is absent, but at Jellico, Tennessee, and at Cumberland Gap it is represented by about 15 feet of thin-bedded chert of typical Fort Payne character.

Thickness. The thickness of the Keokuk rocks, including the Fort Payne, is 250 feet in Jefferson County; 200 feet in Barren and Wayne counties; apparently not over 75 feet on Fishing Creek, Pulaski County, and at Kings Mountain, Lincoln County; less than 75 feet in the vicinity of Junction City, Boyle County; 5 feet or less in Rockcastle County; and 15 feet at Cumberland Gap.

Age and Correlation. The Keokuk age of the rocks described in this section is well enough proven by the fossils listed and cited beyond, as well as by their stratigraphic position below the Warsaw. So far as the writer's experience goes in the study of collections from central Kentucky and northern-middle Tennessee, only one species of brachiopod, *Brachythyris suboricularis*, and only the long-ranging *Cystodictyas* continue from the New Providence into and through the Keokuk rocks. At the very base of these rocks south of Lebanon, Ky., (sec. No. 24 of section chart), the fossils of list No. 17 were collected, and those of list No. 18 were collected just above. Typical New Providence green shale, with a few New Providence fossils, immediately underlies the limestone carrying the fossils of list No. 17. With the few exceptions noted above, none of these forms are recorded from rocks below the Keokuk. From the heavy basal limestone lenses in southern Kentucky and northern

Tennessee a spirifer very like *Sp. montgomeryensis*, if not that species, occurs, and several unlisted crinoids which Springer regards as Keokuk forms could only have come from this bed. On the head of Marrowbone Creek, in Cumberland County, many new species of bryozoa, mainly of *Fenestella* occur, which are apparently without exception different from any in the top of the New Providence from a slightly lower horizon on Beaver Creek in Wayne County. (List No. 7.) In the Jefferson county area, the Kenwood sandstone carries *Productus wortheni*, a Keokuk form, and the higher formations of the Keokuk there carry such characteristic Keokuk forms as *Orthotetes keokuk*, *Rhynchopora beecheri*, *Spirifer crawfordsvillensis*, *Sp. keokuk*, *Sp. montgomeryensis*, *Sp. rostellatus*, and *Syringothyris textus*. Most of these are from the Holtsclaw sandstone, at the top. The Keokuk fauna therefore ranges all through the rocks described under this head from bottom to top. Some of the Keokuk forms pass up into the Warsaw, which, however, has species in its bottom layers that do not occur in the Keokuk. The nearly complete change of fossils in crossing the boundary upward from the New Providence to the Keokuk is explained by the unconformity and time break between them. While fossils are not abundantly distributed through all these rocks of Keokuk age in central Kentucky, the purer limestone lenses are generally well stocked with them. In the siliceous limestone beds and in the shales, fossils are usually scarce but in places at some horizons they become fairly plentiful, especially Bryozoa. The following lists include a fairly complete representation of the fauna. As appears in these lists a good number of undescribed species are present.

LIST NO. 17.

One mile northwest of Calvary, Marion Co., Ky., old quarry of reservoir of Lebanon waterworks. Basal limestone of Fort Payne formation.

Section No. 24, Section Chart.

Agaricocrinus sp.?
Monilopora beecheri Grabau.
Triplophyllum (*Zaphrentis*) *dalei* E. & H.
Triplophyllum (*Zaphrentis*) *centralis* Meek and Worthen.
Lophophyllum, sessile form. New species?

Archimedes negligens Ulrich.
Cystodictya americana Ulrich.
Cystodictya lineata Ulrich.
Cystodictya pustulosa Ulrich.
Cystodictya sp.—much branching.
Cyclopora fungia Prout.
Fenestella rudis Ulrich?
Fenestella cf. *cingulata* Ulrich.
Glyptopora keyserlingi Ulrich.
Hemitrypa proutana Ulrich.
Leioclema punctatum (Hall).
Phractopora megastoma Ulrich.
Phractopora (*Prismopora*) *trifolia* (Rominger).
Polypora retrorsa Ulrich.
Proutella discoidea (Prout).
Streblotrypa major Ulrich.
Taenoidictya ramulosa Ulrich.
Worthenopora spinosa Ulrich.
Cliothyridina parvirostris Meek and Worthen.
Dielasma sp.?
Eumetria?
Orthotetes keokuk?
Reticularia pseudolineata (Hall).
Rhipidomella near *dubia* (Hall).
Spirifer tenuicostatus Hall.
Spiriferina cf. *salemensis* Weller.
Syringothryris?
Tetracamera cf. *subcuneata* (Hall).
Platyceras sp.?

LIST NO. 18.

Bluff below Lebanon water supply reservoir, about 3 miles south of Lebanon, Ky. Fort Payne formation near bottom.

Section No. 24, Section Chart.

Amplexus sp.?
Hemitrypa proutana Ulrich.
Brachythyris suborbicularis (Hall).
Cliothyridina parvirostris (Meek and Worthen).
Chonetes illinoisensis Worthen.
Cyrtina sp.?
Productella n. sp.?
Pseudosyrinx sp.?
Pustula alternata Norwood and Pratten.
Reticularia pseudolineata (Hall).

Spirifer (n. sp.)? cf. sp. *logani* Hall.
Spirifer tenuicostatus Hall.
Spirifcrina sp.?

LIST NO 19.

Cut at south end of railroad tunnel short distance north of Spurlington, Taylor County. Ky., about 20 feet below top of Fort Payne formation.

Athyris cf. *densa*, proportionally longer.
Brachythyris suborbicularis (Hall).
Chonetes illinoisensis Worthen.
Orthotetes keokuk (Hall).
Productella sp.?
Rhipidomella dubia (Hall).
Spirifer keokuk Hall.
Spirifer n. sp. Resembles S. *crawfordsvillensis* Weller. Has the same number but finer ribs, strongly striated radially, transverse striae as in Sp. *crawfordsvillensis*.
Spirifer, n. sp. General type of Sp. *mundulus*. Rowley, but proportionally broader, more plications and stronger transverse striae.
Spirifer tenuicostatus Hall.
Spiriferina n. sp. Like sp. *spinosa* in general form and number of ribs but more finely punctate.
Syringothyris n. sp.
Aviculopecten amplus. M & W.

LIST NO. 20.

King Mountain Lincoln County, Ky. From material from cut at south end of railroad tunnel. Seems to be from near top of Fort Payne formation but may be mixed.

Section No. 22, Section Chart.

Zaphrentis big form.
Taonurus? a fragment suggesting that form.
Brachythyris suborbicularis (Hall).
Productus n. sp.
Pustula alternata (Norwood and Pratten).
Spirifer aff. *montgomeryensis* Weller.
Loxonema?
Straparollus?
Conularia sp.?

LIST NO. 21.

Meshack Creek, Monroe County, Ky. Base of Fort Payne formation.

Section No. 14, Section Chart.

Agaricocrinus americanus Hall.
Eretmocrinus magnificus Lyon and Casseday.
Productus ovatus Hall?
Pseudosyrinx?
Schizophoria sp.?
Spirifer montgomeryensis Weller.
Spirifer aff. *montgomeryensis.*
Igoceras?

LIST NO. 22.

Road between Mitchell Creek and Ward, Overton County, Tenn., in the Standingstone quadrangle. Top of Fort Payne formation.

Monilopora beecheri Grabau.
Batocrinus?
Cystodictya americana Ulrich.
Cystodictya lineata Ulrich.
Cyclopora fungia Prout.
Fenestella multispinosa Ulrich.
Fenestella rudis Ulrich.
Fenestella serrulata Ulrich.
Leioclema gracillum Ulrich.
Polypora near *biseriata* Ulrich.
Polypora halliana Ulrich.
Rhombopora or *Batostomella.*
Vermipora sp.?
Worthenopora spinosa Ulrich.
Orthotetes sp.?
Spirifer sp.?
Spirferina sp.?

LIST NO. 23.

Two miles about due north of Nobob, Barren Co., Ky. About 50 feet below top of Fort Payne formation.

Hadrophyllum n. sp.
Triplophyllum 2 sp.
Brachythyris suborbicularis (Hall).
Cliothyridina obmaxima (McChesney).
Pseudosyrinx sp.?
Spirifer keokuk Hall?
Spirifer sp.?

LIST NO. 24.

Bruce, Barren Co., Ky.

Gray limestone about 30 feet below top of Fort Payne formation.

Brachythyris bruccnis n. sp. cf. Plate 61, fig. 8 Weller, Mon. Miss Brachiopoda.
Brachythyris suborbicularis (Hall).
Orthotetes keokuk (Hall).
Productella sp.?
Productus cf. *setigera* (Hall).
Spirifer keokuk Hall?
Spirifer montgomeryensis Weller.
Spirifer aff. *montgomeryensis.* Finer ribs and less well defined sinus. Transverse striae obscure.

CHAPTER 5.

MERAMEC GROUP

Warsaw Formation

Name and Limits. The Warsaw formation was named from Warsaw, Illinois, where it is well exposed. The name was first published by Hall[28] in 1857, although it had been in use by Worthen and others before.

In central Kentucky the Warsaw includes three members of local though considerable areal extent. These are here named, in ascending order, the Wildie sandstone member, the Somerset shale member, and the Garrett Mill sandstone member. They are described under separate headings, following the description of the formation as a whole.

The Warsaw succeeds the rocks of Keokuk age, and possibly in much of its area there is a slight unconformity between them. The lower limit of the Warsaw in Jefferson County, Ky., is placed at the top of the Holtsclaw sandstone of the Keokuk, while in southern Kentucky, where the Holtsclaw is absent, the lower limit is readily determinable by the differences in the characters of the rocks and fossils of the Keokuk and Warsaw. In the southern country this line of separation is very sharp and can be located within a few feet from the fossils scattered over the ground. On the slopes a mixture of Keokuk and Warsaw fossils can be traced up to a certain level, above which the Keokuk fossils, mainly corals and crinoids, do not go, while the Warsaw forms can be found still higher on the slopes unmixed with the Keokuk forms. Furthermore, none of the Keokuk forms have ever been found in the same layers or loose slabs which in very many places are crowded with the Warsaw fossils. The writer found, too, just such association of fossils under the same conditions as far north as Bloomington, Ind. And this leads to reverting to the discussion of the Keokuk-Warsaw boundary in Jefferson County, Ky., in the section devoted to the description of the Keokuk, p. 73. The doubt about the placing of the boundary at the top of the Holtsclaw arises from the fact that, in Jefferson Co., rocks similar to those of Keokuk type extend

[28] Hall, James, Am. Assoc. Adv. Sci. Proc., Vol. 10, Pt. 2, p. 56, 1857.

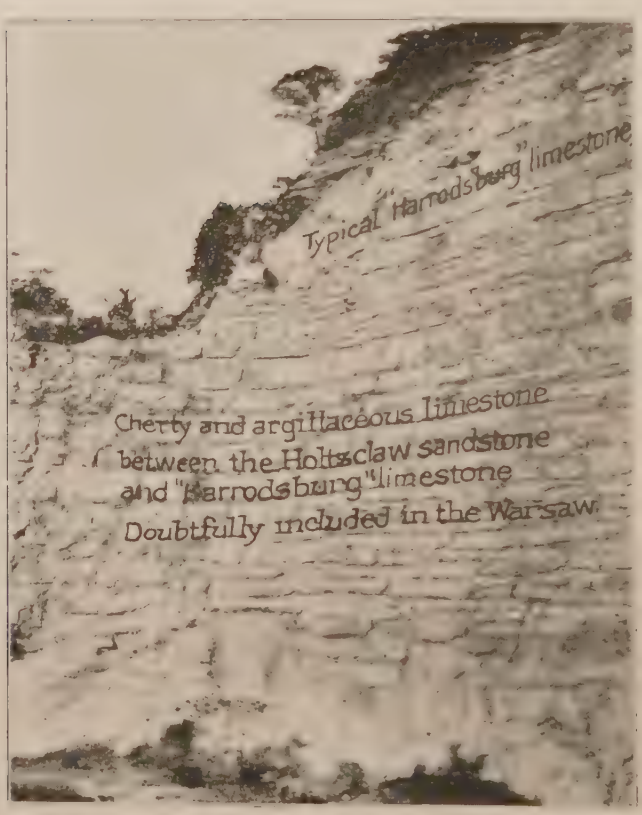


Plate 33. Quarry at West Point, Jefferson County, Ky. Limestone of "Harrodsburg" type above cherty and argillaceous limestone below to top of Rosewood shale a few feet below bottom of quarry. This part doubtfully included in the Warsaw. Looking northeast.

above this contact and carry a few fossils which, at the south, are found only in the Keokuk, such as a large coral, (*Zaphrentis*), calyx plates of a large *Actinocrinus*, *Brachythyris suborbicularis*, and a *Syringothyris*, the last, however, having peculiarities allying it with a form found near Ste. Genevieve, Mo., in rocks about which Ulrich was uncertain whether they are Keokuk or Warsaw. Such fossils have not been found more than 35 feet above the Holtsclaw, and, at one such locality Mitchell Hill, 12 miles south of Louisville, the beds with such fossils are immediately overlain by beds with a Warsaw fauna.

At West Point, Ky., in the old quarry (Pl. 33), the Keokuk type of limestone seems to extend about 60 feet above the probable horizon of the Holtsclaw, and fossils of the Keokuk type were found about 30 feet above. At 50 to 60 feet above the Holtsclaw, typical Warsaw (Harrodsburg) limestone with a profuse Warsaw fauna comes in. On the other hand the oolite bed just above the Holtsclaw, which is included in the Warsaw, carries, along with forms common in the Keokuk rocks, fossils more characteristic of Warsaw. The points of the foregoing discussion are illustrated by sections 3, 6 and 8, of the section chart and by the fossil lists Nos. 25 to 30, inclusive.

It is possible that but a brief interruption in sedimentation marked by the oolite and glaiconite took place in a small area in the Jefferson County region, and that, later, rocks of the Keokuk type were laid down and some of the Keokuk fossils lived on for a time in that basin. In much larger areas, where the rocks and fossils seem to be much more sharply separated, as mentioned, it is possible that there was a longer interruption of sedimentation, and that when those areas were finally resubmerged or the conditions of sedimentation and life returned the Keokuk species had entirely died out and the sea was inhabited only by Warsaw forms.

Distribution. The Warsaw extends throughout central Kentucky and south across Tennessee into Alabama. In eastern Kentucky it was identified as far northeast as a point about 8 miles east of Berea (Secs. Nos. 35 and 36 of section chart), but it is not present at Irvine, about 10 miles farther northeast. It is not present at Pineville or at Cumberland Gap, nor was it detected at Jellico, Tenn., on the west escarpment of Pine Mt. It is present in the north end of Sequatchie Valley, in Cumberland County, Tenn., which locality is in direct continuation of the line of Pine Mt. southwestward. Within the limits outlined the Warsaw is present wherever its horizon has escaped erosion and is exposed to view.

Character. The Warsaw, like the Keokuk, is composed of limestone, shale, and sandstone in varying proportions. Changes from one to the other take place at the same stratigraphic level within short distances. The predominating type of rock, especially in southern Kentucky and northern Tennessee, is a coarse,

highly crinoidal, dark, steely-blue limestone. On weathered surfaces the crinoidal fragments stand out in conspicuous relief, generally exhibiting distinct, although as a usual thing, gently oblique, cross-bedding, which is only brought out by the etching in weathering. This feature is well shown in the photograph plate 34. The layers of the limestone are usually thick and in places even massive. (See Plates 35 and 36.) In Hardin County, Ky., between Colesburg and Tunnel Hill, where the Warsaw has its maximum thickness, there is, in the upper half, a thickness of about 40 feet of rather thin-bedded but coarse,

Plate 34. Nearer view of limestone shown in Plate 35, showing the rough surface and cross lamination characteristic of the limestone of the Warsaw.

bluish or gray limestone, the features of which are shown in Plate 37. As stated in the discussion of the lower boundary of the Warsaw, there is, in Hardin, Bullitt and Jefferson counties, in the lower 30 to 60 feet of the Warsaw, siliceous limestone with chert layers closely resembling parts of the underlying rocks of Keokuk age in southern Kentucky and northern Tennessee. A photograph of the lower part of these beds is shown in Plate 38. With the exception of this lower part of the Warsaw, so far as known limited to the counties named, the limestone of the Warsaw throughout Kentucky and Tennessee is practically identical in lithologic character with the "Harrodsburg" limestone, of Warsaw age, at its type locality, Harrods-

Plate 35. Massive bed of Warsaw limestone in cut on Louisville & Nashville Railroad about midway between Maretburg and Brodhead, Ky. Looking east. Garret Mill sandstone member (very thin) at top of limestone.

Plate 36. Quarry in Warsaw limestone at Glasgow, Ky. About 50 feet of coarse, crinoidal limestone. Looking north. This is a good exhibition of the limestone facies of the Warsaw. The rock here has the same aspect as the Warsaw has southward into Overton County, Tenn., and northward to Harrodsburg, Ind., the type locality of the "Harrodsburg" limestone, which is the partial equivalent of the Warsaw. (See Plate 39).

Plate 37. "Harrodsburg facies" of the Warsaw limestone extending up to the Somerset shale member shown in Plate 49. Cut on the Louisville & Nashville Railroad one-half to one mile north of the tunnel at Tunnel Hill. Looking north. The shaly layer shown in Plate 43 appears at base of cut at the farther end.

burg, Ind. (See Plate 39.) Toward the thin northeast edge of the Warsaw, in Rockcastle, Madison, and Jackson counties, the limestone of the formation is thick-bedded, non-fossiliferous, and yellow, resembling in some respects the lower beds of the Warsaw in Jefferson County, etc. (See photographs, Plates 40 41 and 42.)

At some horizons in the Warsaw, in different localities, are argillaceous limestone layers that weather to an ochreous condition. In Tennessee similarly are sandy layers that weather to friable sandstone by the solution of the limy part, although in the fresh condition they look like pure blue limestone. Fine cross lamination is a characteristic feature of such sandy limestone.

The shale in the Warsaw in some localities makes up a large part of its thickness; usually, however, the limestone predominates. The shale is of a bluish color and does not differ greatly in its appearance from that of the underlying shale of Keokuk age. Shale near the bottom of the formation is shown in Plate

Plate 38. Contact of Warsaw limestone on the Rosewood shale. Limestone 60 feet thick and overlain unformably at least locally by typical "Harrodsburg" facies of the Warsaw. It is a matter of doubt whether this limestone is of Keokuk age or Warsaw. Has been regarded as Warsaw by the author in his report on Jefferson County. Louisville & Nashville Railroad about one mile south of Colesburg. Looking north.

Plate 39. Highway cut one mile south of Harrodsburg, Ind., exposing Warsaw "Harrodsburg" limestone. This is the type section of the "Harrodsburg." Looking northwest.

Plate 40. View of tunnel at Hummel on Knoxville branch, Louisville & Nashville Railroad, 4½ miles northeast of Mt. Vernon. Wildie sandstone member of Warsaw at bottom and thick-bedded yellow Warsaw limestone at top. Looking north. Compare Plates 41, 42, and 46.

Plate 41. View in highway at head of Owsley Branch. Basal heavy limestone of St. Louis with large *Bellerophon* and fucoids at top. Warsaw yellow limestone and shale below. Wildie sandstone member six inches thick just below shale in lower right corner. Looking east.

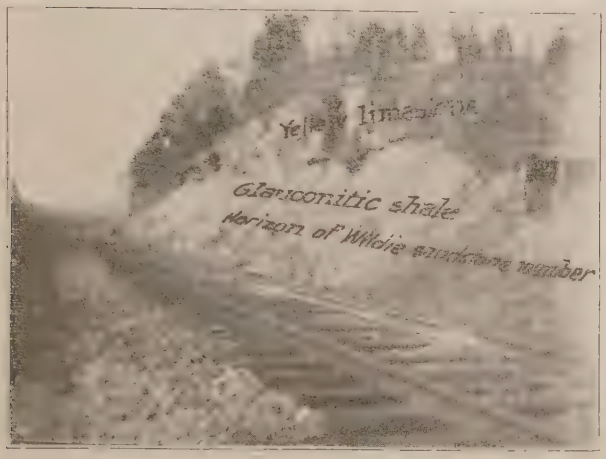


Plate 42. Cut on Louisville & Nashville Railroad about midway between Maretburg and Brodhead. Top of Fort Payne (Keokuk) at bottom showing at far end of cut. Glauconitic shale overlain by yellow Warsaw limestone. Looking west.

42. A thickness of over 20 feet of such shale, forming the lower 20 feet of the Warsaw, is exposed in a shale quarry by the roadside at the crossing of South Fork of Beaver Creek, 1 mile south of Glasgow, Barren County.

Another notable feature of the Warsaw at various points in Kentucky and Tennessee is the geodes. These are hollow bodies of silica of irregular, spherodial, or discoidal shape, that form in the argillaceous or siliceous layers and are liberated on weathering. Such geodes are abundant in the ravines on the knobs in the southern part of Jefferson County, where they are generally spheroidal and reach a diameter of 4 to 6 inches. Very large discoidal geodes, as much as 3 feet in longest diameter, occur near the top of the Warsaw in a considerable area a few miles northeast of Somerset. There is a horizon of large spheroidal geodes about the same horizon near Gunters, Fentress County, Tennessee.

Another lithologic feature is a thin layer of fine conglomerate near or just below the middle of the Warsaw, which was observed only in a road cut at the east end of the bridge across Pitman Creek a few miles northeast of Somerset.

Some Conditions of Warsaw Deposition. The change from shale to limestone, or vice versa, in short distances, of common occurrence in the Warsaw, has been mentioned. Such changes are generally supposed to be gradual transitions from one kind of rock to the other through beds of intermediate character, and that may be the manner of change in some cases but evidently not in all, as demonstrated by exposures along the L. & N. R. R. between Colesburg and Tunnel Hill, shown in Plates 43 and 44. Here such changes are seen to be abrupt, as if

Plate 43. Local bed of shaly argillaceous limestone replacing a part of the 40 feet of thin-bedded gray limestone in the upper half of the Warsaw. Common in the Warsaw of this part of Kentucky. Louisville & Nashville R. R. about one mile north of Tunnel Hill. Looking northwest. Same exposure shown in plate 37, a few rods farther north.

brought about through irregular deposition, first of one kind of rock, then of another, for such abrupt changes would hardly be possible if deposition of the two kinds of material were simultaneous.

Such conditions in the rocks, combined with the universal cross-bedding in the Warsaw limestone, probably indicate shallow water affected by strong waves and currents caused by winds

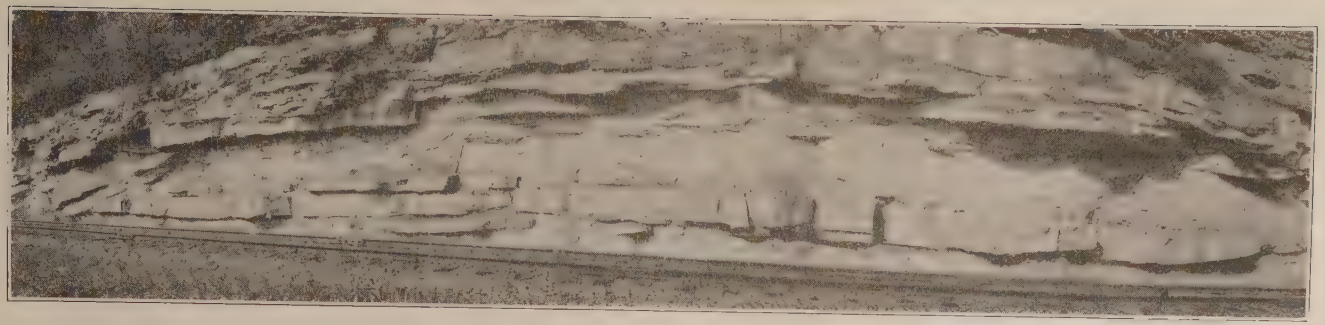


Plate 44. Spally bed in the Warsaw like that shown in Pla te 43 and accompanying irregularities in the heavy compact layers. Louisville & Nashville Railroad about two miles north of Tunnel at Tunnel Hill. Looking west.

and tides. Through such agitation of the water, shifting and redeposition of sediment was continually taking place, tending to local irregularities in the bedding. By shifting of load, increasing pressure in some spots and lessening it in others, slight displacements may have taken place, producing small faults in the semi-lithified lime muds. What appears to be a small fault is shown at the left end of Plate 44, and may have been produced in such a manenr. Furthermore, considerable uplifts seem to have taken place locally, followed by beveling off the upswelled layers which were then covered by the immediately succeding sediment, resulting in local unconformities. Such an unconformity is shown in Plate 45.

This plate is a view of an exposure on the L. & N. R. R. about 1 mile south of Colesburg, Hardin County, Ky., and the unconformity was supposed to mark the boundary between the Warsaw and St. Louis limestones. The section had been hurriedly examined, at a time before the writer had become thoroughly familiar with the characteristics of the two formations, and the conclusion stated was based on the similarity of the succession from the Warsaw to the St. Louis farther west, at Brandenburg, Meade County. The writer is glad to take this opportunity to correct the mistake.

That the unconformity here is probably not of much significance is believed from the fact that it is not present in other exposures of the same beds, as in the quarry at West Point (Plate 33.) Then, too, a short distance beyond the point shown on the left end of Plate 45, the exposure being continuous, the coarse bed above the unconformity pinches out; the beds above and below become parallel and identical in character, even to the chert layers that stand out like ribs from the face of the limestone. It is a fact, however, that the typical, coarse, fossiliferous layers of the Warsaw of "Harrodsburg" type begin at this unconformity, the beds below, about 60 feet thick, down to the well-defined contact with the Rosewood shale, probably belonging to the doubtful basal beds included in the Warsaw, already sufficiently discussed.

Thickness. The Warsaw is about 240 feet thick between Colesburg and Tunnel Hill, Hardin County, and this seems to be about its maximum thickness. It is about 200 feet on the Ohio

Plate 45. Local unconformity in the Warsaw formation. Cut on the Louisville & Nashville R. R. about one mile south of Colesburg, Hardin County. In the report on the Mississippian series in Western Kentucky where this photograph was published as Plate 9 the unconformity was erroneously placed between the Warsaw and St. Louis.

River bluff in Indiana opposite West Point, Ky. It is less than 100 feet at Edwardsville, Ind., several miles northwest of Louisville. In the southern counties of central Kentucky and in northern middle Tennessee it is 80 to 100 feet thick. Its thickness at Burnside, Pulaski County, is 60 feet; on the railroad between Maretburg and Brodhead, Rockcastle County, it is about 50 feet thick; and at the head of Owsley Branch in the western part of Jackson County, it is about 18 feet thick. No determination of its thickness was obtained at any point farther northeast, but it feathers out between the head of Owsley Branch and Irvine, where it is absent. (See sections Nos. 33 to 37, section chart.)

Wildie Sandstone Member. On Town Creek, about 3 miles northeast of Mount Vernon, and 1 mile west of Langford, in the London quadrangle, a thin sandstone comes into the section. This sandstone is here named the Wildie sandstone member, because it is best developed and is extensively quarried in the vicinity of Wildie, Rockcastle County, Ky. At Langford the section described below is exposed. Beneath the sandstone is 15 inches of highly glauconitic shale with black nodules having the appearance of phosphatic nodules. Below the glauconitic layer is about 2 feet of impure fossiliferous limestone. The fossils while quite plenty are poorly preserved, but a few fair specimens were obtained. One species is *Brachythyris suborbicularis* and the other the form identified in the Fort Payne lists as Sp. aff. *montgomeryensis*. There seems no reason to doubt that the limestone layer is Fort Payne. Below the limestone is typical New Providence green shale and sandstone with *Taonurus*. (See Plate 23.) Above the Wildie sandstone member is a few feet of shale and sandstone, above which is about 20 feet of thick-bedded yellow limestone. (See Plate 40.) One mile west of Langford, where the Wildie sandstone member first appears in the section, *Spirifer lateralis* and *Spirifer washingtonensis*, Warsaw species, occur in a layer of gray limestone in the middle of the yellow. All the circumstances point to the correlation of the glauconitic layer in this section with the glauconitic layer at the base of the Warsaw in Jefferson County, so that the Wildie sandstone member is of Warsaw age.

The Wildie sandstone is thick-bedded, very uniformly fine-grained, bluish and of medium hardness. It is a free working stone and makes an excellent building stone and has been and is now utilized for that purpose. It is known to the trade as the "Rockcastle freestone." Present quarrying operations are located somewhat south of Wildie. The Wildie sandstone member and underlying layers are well shown in the Photograph Plate 46.

From the point of its first appearance in the section it thickens to 6 feet at Hummel Station, just north of the Tunnel at Langford. This thickness evidently holds or even increases to

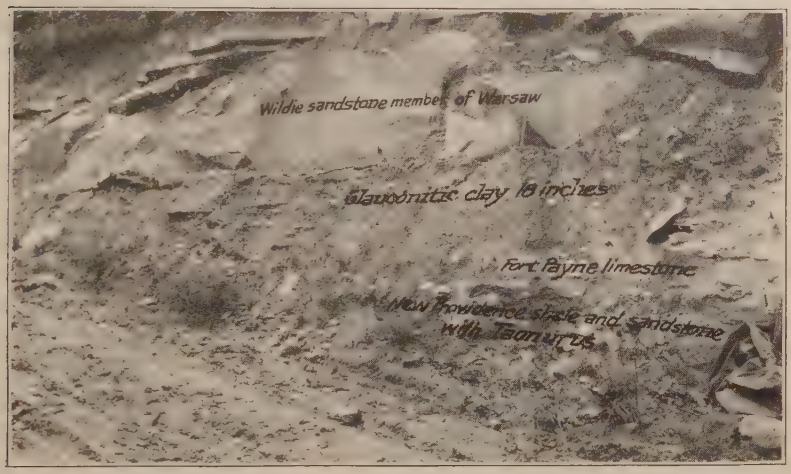

Wildie sandstone member of Warsaw
Glauconitic clay 18 inches
Fort Payne limestone
New Providence shale and sandstone with Taonurus

Plate 46. Road cut at west end of highway bridge at Langford about four miles northeast of Mt. Vernon. Shows Wildie sandstone member of Warsaw underlain by about 18 inches of glauconitic clay, below which is a thin layer of Fort Payne limestone, which is underlain by New Providence shale and sandstone with *Taonurus*. Looking west.

the vicinity of Wildie. At the next nearest northern point where examined, near Morrill, about 5 miles southeast of Berea, and 10 miles northeast of Wildie, the Wildie sandstone is only 1 foot thick, and on Owsley Branch, and on the north side of the ridge between Redlick Creek and Owsley Branch, it is reduced to 6 inches in thickness. It dies out with the remainder of the Warsaw between Owsley Branch and Irvine. Its entire known northeast-southwest extent is about 16 miles and may be 20 miles.

It is a matter of interest that on the escarpment just south of Parksville, in Boyle County, is a soft, thick-bedded sandstone 5 feet thick in the position of the Wildie member and probably to be correlated with it. (See Sec. 25 of section chart.) There is also a sandstone, but apparently at a slightly higher horizon in the Warsaw, at Kings Mountain, showing on the slope above the south portal of the Tunnel. At that point, however, no glauconite was noted and a layer full of Warsaw Bryozoa occurs below the sandstone. It is possible that this too is the Wildie sandstone. It is absent from the section between Maretburg and Brodhead, but this point is south of the latitude of Kings Mountain, and the absence may be accounted for by the fact that the southern margin of the sandstone deposition was approximately along a line drawn from near Kings Mountain to the point north of Mt. Vernon, where the southern edge of the Wildie member appears to lie. A line drawn from Parksville due east will also fall near the known northern limit of the Wildie sandstone member between Owsley Branch and Redlick Creek.

The Wildie sandstone member being the only sandstone of that type in the section is easily recognized from its fragments and is an excellent horizon marker throughout the areas underlain by it.

The glauconitic layer underlying the Wildie sandstone has been observed over almost the whole area of the sandstone, but was not noted at Parksville or Kings Mountain. In the section midway between Maretburg and Brodhead glauconite is plentifully distributed in the 15 feet of shale probably lying above the horizon of the Wildie and the glauconite extends even into the overlying yellow limestone. (See Plate 42.) The richest bed of glauconite is on the head of Owsley Branch. Here the glauconite is concentrated in an 18-inch layer, 4 1-2 feet below the Wildie member, making a hard green rock yielding large, dark green pebbles to the streams.

Somerset Shale Member. The Somerset shale member is named from Somerset, Pulaski County, where it is well displayed in a railroad cut a short distance north of the railroad station. (See photograph Plate 47.) The main reasons for separating this out as a member are that it is the source of the

Plate 47. Cut about one-fourth mile north of railroad station at Somerset, showing Somerset shale member of the Warsaw. Layers of St. Louis limestone at top. Looking north.

many Warsaw fossils at such well known localities as Colesburg and Glasgow, and that it is believed to be persistent throughout most of the Warsaw areas in central Kentucky. Shale with thin limestone layers, highly fossiliferous, believed to be the same as the Somerset, has been observed in the Warsaw near or at the top, at such widely separated localities as Rock Haven, Meade County; Illinois Central R. R. tunnel, 4 miles north of Muldraugh; (See Plate 48); southwest of Colesburg; Tunnel Hill, 4 miles north of Elizabethtown, Hardin County; (See Plate 49.); Glasgow, Finney, and other localities in Barren County; between Spurlington and Campbellsville, Taylor County; and a mile or two southeast of Parksville, Boyle County.

The best exhibition of the member is in the glades on the hill tops 2 miles southwest of Colesburg, and it would have been named Colesburg if that name had not been preoccupied.

The Somerset member is a calcareous shale or shaly limestone with a variable amount of highly fossiliferous limestone

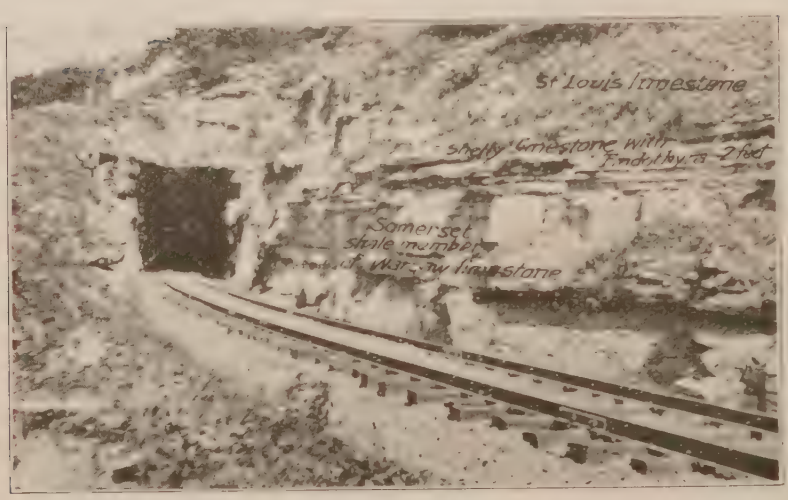


Plate 48. South portal of tunnel on Illinois Central Railroad about four miles north of Muldraugh, Ky. Cut in Somerset shale member of the Warsaw. Looking north.

Plate 49. Cut at south end of tunnel on the L. & N. R. R. at Tunnel Hill, about four miles north of Elizabethtown, Hardin County. Cut in the Somerset shale member of the Warsaw formation. Looking northwest. This is the highly fossiliferous bed yielding the fossils in the glades on the hill at the well-known locality about 2½ miles southwest of Clesburg, Ky. The light colored bed above the portal is the base of the St. Louis limestone; the thick, dark bed just above the shale is in the Warsaw. See Plate 48.

of the usual Warsaw "Harrodsburg" type intercalated in it in thick or thin layers. It is these limestone layers that carry the most of the fossils which are liberated as free specimens on weathering. The shale also is fairly rich in fossils, especially bryozoans and brachiopods. Overlying the shale in most localities are a few feet of thick-bedded limestone with Warsaw fossils, and this is everywhere succeeded by St. Louis limestone, into which none of the characteristic Warsaw forms enter. This thick-bedded limestone making the top of the Warsaw section and, overlying it, the light colored, yellow, basal layer of St. Louis limestone (above the portal) are shown in the photograph Plate 49.

At Somerset the Somerset shale member seems to be about 20 feet thick, at Tunnel Hill it is 25 feet thick, and on the hills southwest of Colesburg it is 50 feet thick. It seems to be nearly as thick on the river bluff in Indiana opposite West Point. In Barren County and at other points mentioned it does not appear anywhere, except possibly just east of Glasgow, to exceed 10 feet in thickness.

The fossiliferous character of the Somerset shale has been mentioned. The shaly beds of the glades southwest of Colesburg and the shaly beds just east of Glasgow have yielded many of the Warsaw fossils that have been described from Kentucky. (See lists 32, 33 and 34.)

Garrett Mill Sandstone Member. The Garrett Mill sandstone member is named from Garrett Mill, on Eagle Creek, 3 miles north-northeast of Livingston, Overton County, Tenn., in the Standingstone quadrangle. The mill stands upon the sandstone, which is a notable water table in the region, upon which a strong spring or underground stream emerges and supplies the power for the mill.

The Garrett Mill sandstone member is generally a flaggy sandstone 5 to 10 feet thick. It is persistent throughout northern Overton County and thence as far north as Pulaski County, Ky., where it is represented by a few inches of sandy limestone at the top of the Warsaw in the bluff of Cumberland River just north of Burnside. Probably too a fine quartz conglomerate at the top of the Warsaw at Mt. Vernon, Rockcastle County, and two miles or so to the northeast, is the Garrett Mill member,

which there may be an outlier or a lagoon-like extension of the main area of the Garrett Mill. Being thin and the only sandstone in a considerable thickness of limestone and thus easily and certainly identifiable and extending over several counties it is of importance as a horizon marker and a datum plane for working out oil structures in those counties which are oil-bearing or prospectively oil-bearing territory. Furthermore, it has been very useful in marking the boundary between the St. Louis limestone and the Warsaw, for the immediately succeeding basal St. Louis sequence, determined for many sections starting at the bottom with the Garrett Mill sandstone member, has been found to extend beyond the areal bounds of the sandstone, so that a sure basis for discriminating the St. Louis from the Warsaw over all of central Kentucky has been acquired. Indeed, the same basal St. Louis features have been found to extend as far north as Bloomington, Ind.

Age and Correlation. The Warsaw age of the rocks designated as Warsaw formation in central Kentucky is unquestioned except, of course, the lower 30 to 60 feet in Jefferson County, Ky., as already discussed. Pp. 89-91. Lists 26 to 31, inclusive, are of fossils from these lower beds. Lists Nos. 26 and 30 are from the oolite bed just above the top of the Holtsclaw sandstone. Nearly all the species identified here occur in both the Keokuk and the Warsaw. Some of the forms of lists Nos. 27 and 28 have not been recorded from the Warsaw. The fossil evidence therefore for these basal beds in Jefferson County and neighborhood is inconclusive. The lithology of the beds also is more like that of the Fort Payne than that of the Warsaw outside of the area outlined. There remains therefore only the oolite layer and the glauconitic clay at the top of the Holtsclaw, and these are believed to indicate physiographic changes and conditions which precede the initiation of a new epoch of deposition and of formational history. The basal Warsaw beds under consideration, with their surviving Keokuk fossils, can be explained by assuming that they were the initial deposits in a rather small area in which deposition was only temporarily suspended, while deposition in the rest of the Warsaw area, in which no such transition beds are present, was not resumed un-

til somewhat later, so that there is an abrupt change from the Keokuk to the Warsaw, with a larger stratigraphic break between. The completeness of the faunal break in such areas, so far as characteristic Keokuk and Warsaw forms are concerned, has already been stated, Page 89.

A number of lists of Warsaw species follow. Only some of the collections from the more important localities have been identified by myself with the help of Ulrich. List No. 25 is a general one to show the Warsaw forms that come in at the very bottom of the Warsaw yet almost without intermixture of Keokuk forms.

LIST NO. 25.

General list of fossils from the bottom and lower part of the Warsaw formation in central Kentucky and northern middle Tennessee.

Metablastus worthèni (Hall).
Talarocrinus simplex (Shumard).
Tricoelocrinus woodmani Meek and Worthen.
Athyris densa Hall.
Orthotetes keokuk (Hall) (occurs in Keokuk.)
Productus corrugatus n. sp.
Productus magnus Meek and Worthen.
Spirifer keokuk Hall, abundant; occurs in Keokuk but not abundant.
Spirifer lateralis Hall, abundant.
Spirifer washingtonensis Weller, abundant.

As stated on Page 89, most of these forms can be found abundantly or occasionally on weathered banks and slopes mingled with very large crinoidal stem plates, bases, and calyx plates, of a large species of *Actinocrinus*, specimens of *Agaricocrinus*, probably *A. nodulosus* and possibly also *A. americanus*, and large corals of the *Triplophyllum dalei* type, none of which occurs in Warsaw beds. The Warsaw forms too occur invariably higher on the slopes above any of the Keokuk forms, not excepting the big stem plates. The Warsaw forms of the latter rarely exceed 1-2 inch in diameter, while the Keokuk forms up to 3-4 of an inch in diameter are everywhere abundant, and a good many reach nearly an inch. The ordinary circular forms are most common, but the elliptical plates of Platycrinus over an inch in longest diameter occur. Not only do these Keokuk

forms not extend up the slopes as high as the Warsaw forms, but they never have been found in association in the same rock with species like *Athyris densa*, *Spirifer lateralis*, and *Spirifer washingtonensis*, which are confined to the Warsaw. In places limestone crowded with these fossils, and more especially with *Spirifer washingtonensis*, lies directly on top of the siliceous limestone or shale of the Keokuk. An example of such an occurrence is on the top of the south bluff of Skeggs Creek about 1 mile southeast of Mathews Mill, in Barren County. Another is on the road between Glasgow and Oil City, a short distance east of the crossing at the railroad trestle across Beaver Creek. At this place *Productus magnus*, *Productus corrugatus* n. sp., and *Orthotetes*, a big species like *O. Keokuk*, and probably that species, occur in association with *Spirifer lateralis*.

The most profuse development of the Warsaw fauna is in the Somerset shale member. The fossils of this member, so far as represented in the writer's collections and identified, are named in lists Nos. 32, 33 and 34.

The only comment on this fauna that will be made here is in regard to its upward range. A very large proportion of the forms listed do not pass above the top of the Warsaw, that is, above the horizon of the Garrett Mill sandstone member, into association with such characteristic St. Louis forms as *Lithostrotion proliferum*, which comes in in places not more than 15 or 20 feet above the horizon of the Garrett Mill sandstone member, as will be shown in the description of the St. Louis limestone. This statement applies to such species as *Triplophyllum compressa*, *Palaeeis cuneiformis*, *Metablastus wortheni*, *Pentremites conoideus*, *Talarocrinus simplex*, the species of *Glyptopora*, *Athyris densa*, *Brachythyris subcardiformis*, *Spirifer lateralis*, *Sp. washingtonensis*, *Spiriferella neglecta*. This list could probably be extended to include most of the species listed from the Somerset member, at least so far as central Kentucky and middle Tennessee are concerned. It is true that such forms as *Pentremites conoideus* and other Warsaw forms are elsewhere listed as derived from the St. Louis*, but that is probably due to the fact that where the St. Louis is present great numbers of silicified coralites of *L. proliferum* roll down the slopes and

*U. S. Geol. Survey, Bull. 688, p. 56, 1919.

become mingled with the Warsaw forms. Not a single case, however, of the occurrence of the two forms in the same beds has ever been found by the writer in the regions named, although observation has been constantly and specifically directed to the determination of this point. Ulrich, though, reports such an association in western Kentucky, and conditions may be different there. In central Kentucky and middle Tennessee then the Warsaw and St. Louis can be unfailingly separated by the use of these fossils. The Warsaw extends as high on the slopes as any of the species named above is found, and the presence of St. Louis limestone higher on the slopes or on the tops of knobs and spurs may be surely inferred from the presence of Lithostrotion in such situations. Any limestone carrying Lithostrotion proliferum or L. Canadense is placed in the St. Louis.

LISTS OF WARSAW FOSSILS.

LIST NO. 26.

Hill top just east of Mt. Carmel School, Jefferson County, Ky., about 10 miles south of Louisville. From oolite bed just above Holtsclaw sandstone.

Section No. 8, Section Chart.

Palaeacis obtusus Meek and Worthen.
Archimedes negligens Ulrich.
Bactropora simplex Ulrich.
Cyclopora fungia Prout.
Fenestella serrulata Ulrich.
Fenestella tenax Ulrich.
Glyptopora sagenella Ulrich.
Leioclema foliatum Ulrich.
Leioclema punctatum (Hall).
Polypora biseriata Ulrich.
Proutella discoidea (Prout).
Stenopora tuberculata Ulrich.
Streblotrypa radialis Ulrich.
Worthenopora spinosa Ulrich.
Reticularia setigera (Hall).
Rhipidomella dubia (Hall).

LIST NO. 27.

Old quarry at West Point, Jefferson Co., Ky., 10 to 25 feet above bottom of Warsaw formation.

Section No. 3, Section Chart.

Amplexus, large species. Same at Mitchell hill, at same horizon.
Archimedes negligens Ulrich.
Fenestella serratula Ulrich.
Fenestella sp.?
Brachythyris suborbicularis (Hall).
Spirifer aff. montgomeryensis Weller.
Syringothyris sp., distinct septum in dorsal valve. Same or closely related form from Ste. Genevieve, Mo., in beds referred by Ulrich with doubt to upper Keokuk.

LIST NO. 28

Mitchell Hill road, on south side of hill, about 12 miles south of Louisville, Ky., in the Kosmosdale quadrangle. Thirty to 25 feet above the Holtsclaw sandstone.

Section No. 8, Section Chart.

Amplexus, large special. Same at quarry at West Point at same horizon.
Triplophyllum (*Zaphentis*) *dalei* (E. & H.)
Platycrinus.
Fenestella several species, probably undescribed.
Brachythyris suborbicularis (Hall).
Chonetes illinoisensis Worthen.
Chonetes sp., coarse costae about 4 to MM and shallow mesial sinus. nearest to *C. ornatus*.
Productus sp.? rather large.
Rhipidomella dubia (Hall)?
Rhynchopora beecheri Greger.
Spirifer keokuk Hall.
Spirifer tenuicostatus Hall.
Spirifer washingtonensis Weller?
Spiriferina norwoodana Hall? much larger.

LIST NO. 29.

Mitchell Hill, 35 to 45 feet above Holtsclaw sandstone.

Section No. 8, Section Chart.

Triplophyllum compressa (E. & H.)
Talarocrinus simplex (Shumard).
Reticularia setigera (Hall).
Spirifer keokuk Hall.
Spirifer tenuicostatus Hall.
Spirifer washingtonensis Weller.
Spiriferella neglecta (Hall)?

LIST NO. 30.

One mile north of Farabee, Ind. Oolite just above Holtsclaw. sandstone.

Section No. 30, Section Chart.

Athyris sp.
Camarotoechia sp.?
Chonetes illinoisensis Worthen.
Eumetria verneuiliana (Hall).
Dielasma sp.?
Paraphorpyhnchus? Striated Rhynchonellid.
Productus sp.? cf. *P. burlingtonensis* Hall.
Pustula biseriata Hall.
Reticularia pseudolineata (Hall).
Spirifer tenuicostatus Hall.
Spiriferina norwoodana Hall? larger.
Syringothyris sp.?
Tetracamera subcuneata (Hall).

LIST No. 31.

Three-fourths of a mile west of Borden, Indiana just above Holtsclaw sandstone.

Section No. 2, Plate 50.

Cystodictya lineata Ulrich.
Cystodictya pustulosa Ulrich.
Fenestella serratula Ulrich.
Hemitrypa proutana Ulrich.
Rhombopora attenuata Ulrich.
Worthenopora spinosa Ulrich.
Chonetes illinoisensis Worthen.
Spiriferina norwoodana Hall? larger than typical.
Cypricardinia sp.?

LIST NO. 32.

Top of bluff of Ohio River in Indiana, opposite West Point, Kentucky. Somerset shale member of Warsaw formation.

Section No. 5, Plate 50.

Syringopora? monroense Beede.
Triplophyllum calcariformis (Hall).
Triplophyllum compressa (E. & H.)
Pentremites conoideus Hall.
Platycrinus boonevillensis Miller?
Synbathocrinus swallowi Hall.
Talarocrinus simplex (Shumard).
Brachythyris subcardiformis (Hall).

Cliothyridina hirsuta Hall.
Composita trinuclea (Hall).
Reticularia setigera (Hall).
Rhipidomella dubia (Hall).
Spirifer keokuk Hall.
Spirifer lateralis Hall.

LIST NO. 33.

Hill about 2 miles southwest of Colesburg, Hardin Co., Ky. Someret shale member of the Warsaw formation, the Upper 50 feet of the Warsaw.

Section No. 11, Section Chart.

Bordenia zaphrentiformis Greene.
Cystelasma sp.
Monilopora beecheri Grabau?
Palaeacis cuneiformis Edwards and Haime.
Syringopora? monroense Beede.
Triplophyllum calcariformis (Hall).
Triplophyllum compressa Edwards and Haime.
Batocrinus decoris Miller.
Batocrinus icosodactylus Casseday.
Batocrinus irregularis Casseday.
Batocrinus sacculus Miller and Gurley.
Metablastus wortheni (Hall).
Pentremites conoideus Hall.
Pentremites cavus Ulrich.
Platycrinus boonvillensis Miller?
Synbathocrinus swallowi Hall.
Talarocrinus simplex (Shumard)
Cystodictya lineata Ulrich.
Cystodictya pustulosa Ulrich.
Dichotrypa flabellum Rominger.
Dichotrypa lyroides Ulrich.
Fenestella compressa var. *nododorsalis* Ulrich?
Fenestella serratula.
Fenestella sp.?
Fistulipora spergenense Rominger.
Hemitrypa proutana Ulrich.
Fenestralia sancti-ludovici Ulrich.
Polypora biseriata Ulrich.
Polypora varsoviensis Prout.
Rhombopora sp.?
Stenopora tuberculata (Prout)
Worthenopora spinosa Ulrich.
Athyris densa Hall.
Brachythyris subcardiformis (Hall).

Camarotoechia grosvenori (Hall).
Cliothyridina hirsuta (Hall).
Composita trinuclea (Hall).
Dielasma formosa (Hall)?
Eumetria verneuiliana (Hall).
Girtyella turgida (Hall).
Productus altonensis Norwood and Pratten.
Pustula biseriata (Hall).
Reticularia setigera (Hall).
Rhipidomella dubia (Hall).
Spirifer keokuk Hall.
Spirifer lateralis.
Spirifer tenuicostatus Hall.
Spirifer washingtonensis Weller
Spiriferella neglecta (Hall).
Spiriferina salemensis Weller?
Tetracamera subcuneata (Hall).
Bellerophon sublaevis Hall?
Cyclonema leavenworthana Hall.
Euomphalus, high spired form.
Orthonychia aculirostre (Hall).
Platyceras circulare Rowley.
Coiled cephalopod.
Griffithedes bufo Meek and Worthen?

LIST NO. 34.

Hill about 1 mile east of Glasgow, Barren Co., Ky. Somerset shale member of the Warsaw formation.

Section No. 12, Section Chart

Cyathaxonia?
Michelinia sp.?
Monilipora beecheri Grabau?
Palaeacis cuneiformis E. & H.
Syringopora sp.?
Triplophyllum calcariformis (Hall).
Triplophyllum compressa (E. & H.)
Batocrinus decoris Miller.
Batocrinus icosodactylus Casseday.
Batocrinus irregularis Casseday.
Batocrinus sacculus Miller and Gurley.
Forbesiocrinus saffordi Hall.
Metablastus wortheni (Hall).
Pentremites conoides Hall.
Platycrinus.

Synbathocrinus swallowi Hall.
Talarocrinus simplex (Shumard).
Cystodictya lineata Ulrich.
Dichotrypa flabellum Rominger.
Dichotrypa lyroides Ulrich.
Glyptopora n. sp. with large deep cups.
Hemitrypa proutana Ulrich.
Brachythyris subcardiformis (Hall).
Eumetria verneuiliana (Hall).
Orthotetes?
Reticularia setigera (Hall).
Rhipidomella dubia (Hall).
Spirifer keokuk Hall.
Spirifer lateralis Hall.
Spiriferella neglecta (Hall).
Spiriferina aff. *transversa* (McChesney).
Platyceras circulare Rowley.
Pleurotomaria sp.

LIST NO. 35.

Road short distanct east of crossing of Beaver Creek on road from Glasgow to Oil City, Barren County, Ky. Warsaw formation, very bottom.

Section No 12, Section Chart

Athyris densa Hall? this species or very close to it.
Orthotetes keokuk (Hall)?
Productus magnus Meek and Worthen.
Productus corrguatus n. sp.
Spirifer lateralis Hall.
Spirifer sp. very short and broad form like *sp. mundulus*. Seems to be same as such form at Spurlington in upper part of Fort Payne.
Spiriferella neglecta (Hall).

LIST NO. 36.

Monroe County, Ky. Fountain Run road midway between Flippen and Mudlick. Probably from Somerset shale member of the Warsaw Formation.

Ceratopora agglomerata Grabau.
Palaeacis cuneiformis E. & H.
Triplophyllum calcariformis (Hall).
Triplophyllum compressa (E. & H.)
Talarocrinus simplex (Shumard)
Dichotrypa lyroides Ulrich.
Athyris densa Hall.

Cliothyridina hirsuta (Hall).
Pustula biseriata (Hall).
Rhipidomella dubia (Hall).
Spirifer keokuk (Hall)?
Spirifer lateralis Hall?
Spiriferella neglecta (Hall).

LIST NO. 37.

Cut on Louisville and Nashville railroad midway between Maretburg and Broadhead, Rockcastle Co., Ky. Massive limestone bed in top of Warsaw formation.

Section No. 29, Section Chart.

Monilipora sp.? cf. *M. Beecheri* Grabau.
Triplophyllum calcariformis (Hall).
Metablastus wortheni (Hall)?
Talarocrinus simplex (Shumard).
Cystodictya lineata Ulrich
Fenestella serratula Ulrich?
Glyptopora michilinia Ulrich.
Hemitrypa proutana Ulrich.
Leioclema punctatum (Hall).
Athyris?
Cliothyridina sp.?
Crania sp.?
Eumetria verneuiliana (Hall).
Reticularia setigera (Hall).
Spirifer keokuk (Hall).
Spirifer tenuicostatus (Hall).
Tetracamera subcuneata (Hall).

Relations of the Warsaw Formation of Kentucky and the Spergen and Warsaw ("Harrodsburg") Limestones of Indiana. In south-central Indiana, particularly in Monroe, Lawrence and Washington counties, the limestone between the same upper and lower limits as the Warsaw of Kentucky, as here interpreted by the author, is divided into two formations, the Warsaw ("Harrodsburg") limestone below and the Spergen limestone above, the Spergen being called the Salem limestone by Indiana geologists. The name Spergen, from Spergen Hill, now Norris Station, on the Monon Railroad in Washington County, Ind., has, however, been adopted by the United States Geological Survey. The Spergen is the well-known "Bedford oolite" extensively used for building stone in the eastern United States.

The "Harrodsburg" limestone of Indiana has been generally recognized as of Warsaw age, but the writer questions the generally accepted view that the Indiana Spergen is a distinct formation later than the Warsaw. In order if possible to clear up the doubt the writer examined sections at Harrodsburg, Spergen Hill, and Borden, which tied in fairly closely with sections previously studied at Edwardsville, and south to West Point, Ky. The type section of Harrodsburg is fully described below for the bearing it has on the question in hand as will appear at the conclusion of this discussion:

Section of limestones between the Holtsclaw sandstone (of Keokuk age) and St. Louis limestone 1 mile south of Harrodsburg, Indiana.

		Feet
St. Louis limestone:		
10.	Limestone, blue, slabby, in place?	2
9.	Not exposed slabs of blue limestone with fucoids. *Archeocidaris* and corals	12
Spergen limestone:		
8.	Limestone, gray, shelly, *Endothyra*	2
7.	Limestone, gray, crinoidal, *Pentremites conoideus* and other Warsaw forms	3
	Not exposed	5
6.	Limestone, argillaceous, shaly. Bastard rock of quarrymen	10
5.	Partly exposed, probably to be included in quarry rock	5
4.	Limestone, massively bedded, composed of fossil fragments (coquina) and full of small gastropods (snails) and Pelecypods (clams) and of *Endothyra*, typical Spergen limestone (quarry rock)	60
"Harrodsburg" limestone:		
3.	Limestone, thick bedded, coarse, crinoidal, cross bedded, bluish, bottom 5 feet yellow	56
2.	Shale	4
	Total Spergen and "Harrodsburg"	145
Holtsclaw sandstone:		
1.	Sandstone exposed	1

The three members of this section of especial importance in this discussion for their bearing on Correlation are Nos. 6, 7 and 8. The Spergen holds about the same thickness as in this section as far south at least as Bedford, the center of the quarry-

ing industry. Between Bedford and Spergen Hill, the type locality, the limestone of strictly Spergen type, appears to become thinner, for at Spergen Hill (Norris), so far as exposures afford information, it is only about 20 feet thick. It is possible, however, that it may be somewhat thicker, for there is a considerable unexposed space above the top of the exposed Spergen. The belief of southward thinning is borne out, however. by the section southwest of Borden, in Washington County, where a bed of the Spergen type of rock 5 feet thick lies not over 50 feet below the St. Louis limestone, as shown in Sec. No. 2, Plate 50. Still further south, at Edwardsville, (Sec. No. 3, Plate 50), no limestone of Spergen type is present, although thin limestone layers in a few feet of shale carry *Endothyra* and a few other Spergen fossils. Loose specimens of *Lithostrotion basaltiforme* (*canadense*) occur in the bank just above these layers, and, as the slope above is not very high, it is evident that St. Louis limestone closely overlies the layers with the Spergen fossils. On the river bluff in Indiana opposite West Point, Ky., the layer with *Endothyra* is a thin shaly limestone probably about 2 feet thick between the Somerset shale member of the Warsaw and the St. Louis. At the Tunnel on the Illinois Central R. R., about midway between West Point and Muldraugh Hill station, the *Endothyra* zone with same character and thickness is present. That is the only point in Kentucky and the most southern point at which it was observed. No beds of the Spergen type of lithology, and none of the characteristic Spergen fossils except the *Endothyra* as noted above, have been observed by the writer in Kentucky, and it is certain that the typical Spergen does not extend so far south. Indeed, it probably does not extend far south of Borden, Ind. The writer's interpretation of the evidence is this: The *Endothyra* zone at the top of the Warsaw in southern Indiana and adjoining part of Kentucky is the same as the *Endothyra* zone (No. 8) at the top of the Harrodsburg section, and the Somerset shale member of the Warsaw of Kentucky is the same as the bastard limestone and overlying fossiliferous limestone (Nos. 6 and 7) of the Harrodsburg section. According to this interpretation the Spergen falls within the limits of the upper half of the Warsaw of Kentucky, of which, in Indiana, it is, in the writer's

opinion, a local lithologic facies characterized by the peculiar diminutive fauna widely known as the Spergen fauna. While these small fossils are unknown in the "Harrodsburg" beds at Harrodsburg or in the Warsaw of Kentucky, the Warsaw fauna, such as listed from the Somerset shale member (list Nos. 33 and 34), occurs all through the Spergen limestone in association with its geographically and stratigraphically localized peculiar diminutive fauna.

It may be stated in conclusion that the limestone beds in the Kentucky Warsaw are strictly of the type of the "Harrodsburg" limestone and carry its identical fauna from top to bottom.

The alternative to the hypothesis advanced above is that the Spergen is a younger formation than the Warsaw overlapping from the west and feathering out above the Warsaw of Kentucky and southern Indiana. If that is the correct interpretation of the situation the Spergen is a lithologic and chronologic unit coordinate with the Warsaw. The final solution of the problem awaits further detailed field work.

The author's interpretation of the correlation is indicated by the dotted line in Plate 50, sections 1 to 3, and the alternative interpretation is represented by the heavy dashed line between the same sections.

St. Louis Limestone.

Name and Limits. The St. Louis limestone was named from St. Louis, Mo., the name having been first used by Engleman[28] in 1847. St. Louis is located upon an area underlain by the limestone, which outcrops along the bluffs of the Mississippi, making conspicuous cliffs. As originally delimited or commonly used the St. Louis included the Warsaw limestone, the Spergen limestone, and the Ste. Genevieve limestone, all of which were later separated as distinct units. In various writings on Kentucky geology, also, more particularly by the earlier authors, the name St. Louis included Warsaw and Ste. Genevieve. The boundary between the St. Louis and the Warsaw as here interpreted is, on exposed surfaces, easily enough located by the differences in the lithology and, where not exposed, can be located

[28] Engleman, George, Am. Jour. Sci., 2d Ser., Vol. 3, pp. 119-120, 1847.

within narrow limits by the aid of fossils and chert debris. As already stated, in parts of southern Kentucky, Wayne County, for example, the top of the Warsaw is marked by the thin Garrett Mill sandstone member.

As stated also, the basal part of the St. Louis has an easily recognized sequence of beds, which seems to be nearly invariable throughout its extent in southern and eastern Kentucky and northern-middle Tennessee. A few representative sections are given below:

Section of the top of the Warsaw and the basal part of the St. Louis limestone in the road 1 mile west of Monroe, Overton Co., Tenn.

St. Louis limestone:

4.	Limestone, blue, *Lithostrotion proliferum* and *Archeocidaris*	5
3.	Limestone, greenish, argillaceous, weathers to green clay	10
2.	Limestone, blue	5

Warsaw formation, Garrett Mill sandstone member:

1.	Limestone, sandy and argillaceous with sandstone layers	5

Section near power plant on Elk Spring Creek about 1½ miles southwest of Monticello, Wayne County, Ky.

St. Louis limestone:

		Feet
8.	Limestone, hard, blue, *Lithosrtotion proliferum*, *Archeodidaris*, *Melonites*	10
7.	Limestone, thick-bedded, argillaceous, gray	13
6.	Limestone, thin-bedded, argillaceous, shaly	3
5.	Clay	1
4.	Limestone, argillaceous	1
3.	Shale, green	3

Warsaw formation, Garrett Mill sandstone member:

2.	Sandstone thin-bedded to shaly	3
1.	Limestone, Warsaw type of rock	50

A photograph of this section is shown in Plate 51.

Section in railroad cut in western outskirts of Somerset, Ky.

St. Louis limestone:

7.	Limestone, blue, pure, black chert, *Archeocidaris* spines and plates, *Melonites* plates, fucoids	2
6.	Limestone, argillaceous; shale partings	6
5.	Limestone, massive, argillaceous, gray, fucoids abundant	10

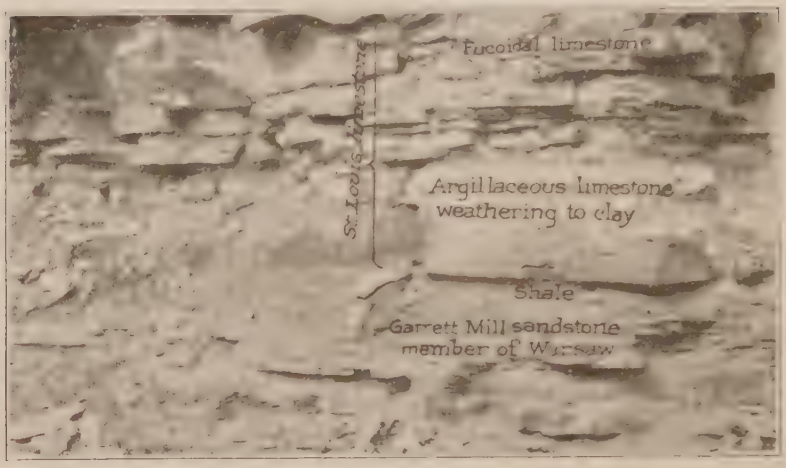


Plate 51. Road cut one-eighth of a mile south of bridge across Beaver Creek on Albany road about two miles southwest of Monticello. Shows Warsaw formation below, with flaggy sandstone (Garrett Mill member) at top, and St. Louis limestone above, with argillaceous limestone at bottom, weathering to clay. Constant features southward into Tennessee. The Garrett Mill sandstone in the Warsaw does not persist northward beyond Wayne County.

4.	Limestone, argillaceous, shale partings, probably weathers to clay	4
3.	Limestone, blue, pure	11
2.	Clay, red streaks	2

Warsaw limestone:

1.	Limestone, coarse, crinoidal	5

This section is shown in Plate 52.

Section on Slick Rock Creek near Barren-Metcalfe County line, 10 Miles East of Glasgow, Ky.

St. Louis limestone:

5.	Banks with *Lithostrotion*, both species.	
4.	Limestone, dark, thick-bedded, chalky	20
3.	Limestone, argillaceoue, fucoids, *Archeocidaris*	20
2.	Limestone, argillaceous, shaly	15

Warsaw limestone:

1.	Limestone, dark, coarse, fossiliferous	20

Section on the Head of Owsley Branch 8 Miles East of Berea, Madison Co., Ky.

Ste. Genevieve limestone:

St. Louis limestone:

		Feet
8.	Limestone, weathers white or yellow, shelly	5
7.	Limestone, thick-bedded, cherty, *Lithostrotion* bearing bed	10

6.	Limestone, argillaceous, spally, yellow	28
5.	Limestone, massive	5
4.	Limestone, argillaceous	2
3.	Limestone, massive, fucoids, *Bellerophon*	5
2.	Shale, green	2
	Total St. Louis	55

Warsaw limestone:

1.	Limestone, siliceous, yellow, spally, cherty, sponge spicules, large geodes	9

Plate 52. Cut on Cincinnati Southern Railroad about one mile north of the railroad station at Somerset, Ky. The lowest limestone just above track level is the top of the Warsaw formation. The rest of the exposure is St. Louis limestone. Argillaceous limestone bed weathering to green clay next above Warsaw; thick fucoidal bed in middle; and pure blue limestone with *Archeocidoris* spines at top. Looking northwest.

The succession here is shown in Plate 41, Page 96.

The succession from the Warsaw into the basal St. Louis where the Garrett Mill sandstone member is absent is shown in Plates 52 and 53.

The succession from the Warsaw through argillaceous thick-bedded limestone with fucoids and *Archeocidaris* and commonly *Melonites* plates, to pure, bluish limestone with *Lithostrotion* is a constant feature of the basal St. Louis in Kentucky and Ten-

Plate 53. Contact of St. Louis limestone on Warsaw formation. Road from railroad station down bluff at Burnside, Ky. Looking southeast. The difference in the bedding characteristic of the St. Louis and Warsaw is plainly shown. The top bed of the Warsaw is massively bedded and rough surfaced; the St. Louis is in rather thick argillaceous, smooth-faced layers with abundant fucoids.

nessee, and probably also in Indiana, as indicated in the section at Harrodsburg, Indiana, (p. 118, and Sec. No. 1, Plate 50.) Accompanying this lithologic and fossil sequence is the absence of all the characteristic Warsaw fossils, which end abruptly with the coarse crinoidal limestone at the top of the Warsaw. The top of the St. Louis is generally easily recognized throughout Kentucky by the appearance of the white or light gray oolite of the Ste. Genevieve. Oolite does not occur in the St. Louis of central Kentucky so far as the writer has observed. The appearance of the oolite going upward in rock succession is accompanied by fossils that do not occur in the St. Louis, or are very rare, such as *Platycrinus penicillus* (huntsvillae.) The St. Louis and Ste. Genevieve can usually be distinguished also by the chert on the surface, the Ste. Genevieve chert preserving the oolitic structure of the limestone from which it is derived through silicification.

Distribution. The St. Louis limestone occupies a belt starting in Meade County, at Ohio River, and passing southward across the state through Hardin, Larue, eastern Hart, northern

Barren, eastern Warren, and Simpson counties. On the east a relatively narrow belt extends through Clinton, Wayne, Pulaski (east of Fishing Creek), and Rockcastle counties; northeast of Rockcastle County the St. Louis makes a relatively small part of the thickness of the limestone capping the escarpment of New Providence rocks as far north as Frenchburg, not far northeast of which it thins out completely. In Virginia the St. Louis is known to extend north as far as northern Russell County, where it is represented in the Newman limestone. According to present knowledge, therefore, the northeast boundary of the St. Louis in Kentucky lies near a line drawn from the vicinity of Frenchburg, Menifee County, to the Breaks of Sandy. The St. Louis is present at Pineville but not at Cumberland Gap. From its northeast boundary southwest to Tennessee, beneath the eastern Kentucky coal field, the St. Louis doubtless forms the basal part of the big lime of the oil well drillers.

Character. Except for the argillaceous layers in the lower part, shown in the sections, pp. 121-123, the St. Louis is mainly a medium thick-bedded, fine-grained, dark to black limestone. Blue and gray layers occur either of which may be compact and some of which are of such fine texture as to constitute a lithographic stone. Several layers of such limestone occur in the St. Louis at Brandenburg, Meade County, and are being utilized to some extent. No such coarse, crinoidal, cross-bedded limestone as that which is so prominent a constituent of the Warsaw formation occurs in the St. Louis of Kentucky. The St. Louis everywhere yields great quantities of compact, yellowish chert, much of which is of chalky texture. All along its eastern outcrop as far north as Mt. Vernon, Rockcastle County, the top 10 feet of the St. Louis is full of nodules of black chert associated in places with numbers of heads of the coral *Litrostrotion*. This bed is shown in the photograph, Plate 54. It is so constant and easily identified that it can be utilized as a datum plane in determining the geologic structure. This upper bed includes dark, drab, or white crystalline layers but no oolite. On the head of Owsley Branch, east of Berea, the middle part of the St. Louis is a yellow spally limestone. It is No. 6 of the section on p. 123. The most southern occurrence of a notably yellow layer in the St. Louis is between Maretburg and

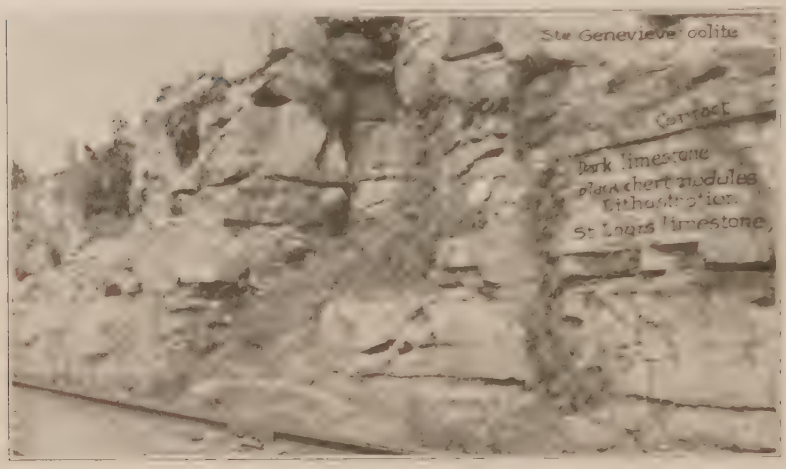


Plate 54. Cut on Louisville & Nashville railroad about one-half mile east of Mt. Vernon, Rockcastle County. Contact of Ste. Genevieve and St. Louis marked by head of hammer. Book lies on cherty bed of St. Louis full of *Lithostrotion Proliferum.*

Brodhead, on the Louisville & Nashville Railroad, the layer there being near the middle of the St. Louis and full of *Fenestellids.* From this point the proportion of yellow limestone seems to increase northeastward, as indicated by its thickness in the section at the head of Owsley Branch. At Irvine neither the Warsaw nor the argillaceous, massive, fucioidal basal layers of the St. Louis are present; but only the yellow limestone, 17 feet thick, lying upon the New Providence and the dark cherty limestone with *Lithostrotion* 8 feet thick at top, the entire St. Louis being only 25 feet thick. The yellow limestone carries fucoids and *Bellerophon.* From Irvine northeastward both the yellow limestone, everywhere lying upon the New Providence, and the overlying dark limestone with black chert and *Lithostrotion* persist to Frenchburg, the most northeastern point at which the St. Louis was observed. At Pineville the St. Louis is composed of thick-bedded fine-grained, dark, greenish, bluish, or gray limestone with considerable chert in black nodules and plates. It is clearly the St. Louis type of lithology. (See Plate 55.)

Thickness. In its western belt from Ohio River to southern Kentucky the St. Louis is in the neighborhood of 300 feet thick.

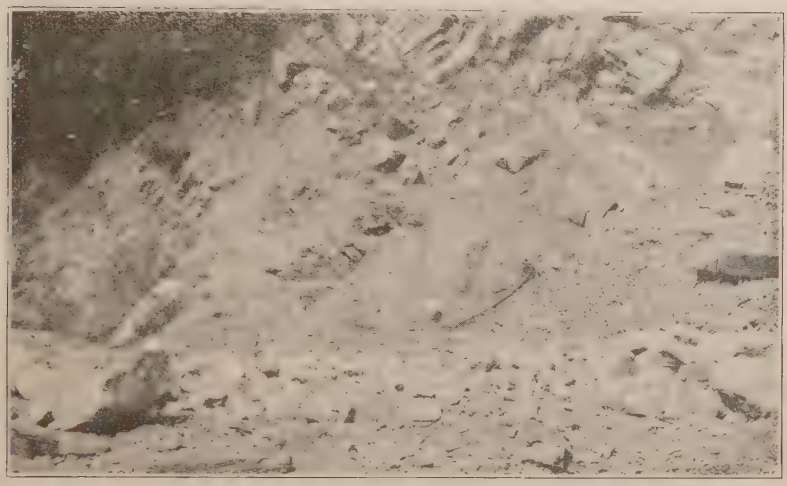


Plate 55. St. Louis limestone overlying New Providence formation. Quarry just south of Pineville, Ky. Looking northeast.

The best determination has been obtained from well borings in Barren County. No good determination has been obtained near Ohio River, but Ashley[29] has estimated the thickness of the Mitchell limestone of Indiana to be between 350 and 400 feet. As the Mitchell includes the Ste. Genevieve, which is about 160 feet thick, it leaves 190 to 240 feet for the St. Louis. On the eastern belt of outcrop the St. Louis is 100 to 120 feet thick in southern Kentucky, 117 feet at Monticello, 100 feet at Burnside, 120 feet at the base of Green River Knob in the southern corner of Casey County, about 100 feet at Somerset, 65 feet at Mt. Vernon, 55 feet on the head of Owsley Branch, 8 miles east of Berea; 25 feet at Irvine, about 20 feet at Yellow Rock, on Kentucky River, between Irvine and Beattyville (See photographs Plates 56 and 57); 20 feet between Glencairn and Tarrant, Wolfe County, and 30 feet at Frenchburg. In the section at Paragon, 15 miles northeast of Frenchburg, the St. Louis is not present, the Ste. Genevieve there resting upon the New Providence. At Pineville the St. Louis is 115 feet thick.

[29] Ashley, Geo. H., The lower Carboniferous area of southern Indiana. Twenty-seventh Ann. Rept., Dept. Geol. & Nat. Res. of Indiana, pp. 49-122. 1902.

Fossils and Correlation. The St. Louis in central Kentucky while not to be considered a scantily fossiliferous limestone is yet not as richly fossiliferous as the Warsaw and has nowhere yielded such an abundance of well-preserved fossils. Fenestellid bryozoa, *Fenestella*, *Polypora*, *Hemitrypa*, in profusion of individuals but few species, occur in some layers where their exposed edges are conspicuous. *Cystodictya* is common and a species apparently of *Dichotrypa* less so. Casts and moulds of these forms can be obtained in the soft chert, but the surface features desirable for satisfactory study and for determination of species are not preserved. A species of *Hemitrypa* having dissepiments elevated and continuous on the reverse occurs and has not been observed in the Keokuk or Warsaw of the region but the same form occurs in the upper beds of the St. Louis on Ohio River in southeastern Illinois. Species of *Spirifer* of the leidevi or bifurcatus type occur. One species at least seems to be undescribed. A *camarotoechia*, probably *C. mutata* occurs. There are two species of *Myalina*, a *Straparollus* or two, a *Bellerophon* rather common in some layers and localities, probably *B. sublaevis*, and in one lot, a *Dentalium*. The *Archaocidaris* spines and plates, *Melonites* plates, and fucoids, occurring in the basal beds, have already been cited. The most common, conspicuous, and important fossils, however, are the two species of the coral *Lithostrotion* which occur as compact heads or more or less irregularly sprawling masses in the layers, in which they become silicified and from which they commonly weather out and become scattered over the surface underlain by the St. Louis. These silicified heads or masses are up to a foot or more in diameter, forming curious and striking objects often called fossil hornets' nests. On extreme weathering the heads break down into the individual coralites which roll down the slopes upon the surface of the Warsaw and so become mixed with the Warsaw fossils and thus *Lithostrotion* finds its way into lists of Warsaw fossils or vice verse. In reality *Lithostrotion* does not occur in the Warsaw beds of central Kentucky. These individual coralites remain in the soil on the tops of knobs and spurs and serve to determine the presence of the St. Louis in such situations—a thin layer capping the tops—or the presence of the residuum of such a layer recently removed leaving the silicified

coralites as evidence of its actual or recent presence. *Lithostrotion*, probably both species, ranges through the full thickness of the St. Louis above the basal 15 to 20 feet of predominantly argillaceous limestone. In eastern Kentucky, where observations have been most extensive, heads of one or both species are by far most abundant in the top 10 feet of mostly dark limestone full of nodules of black chert. *Lithostrotion proliferum* is the form most common, if not the only one, in the lower part of the St. Louis. North of the latitude of Berea, where the lower part of the St. Louis is yellow limestone, *Lithostrotion* occurs only in the upper 10 feet of dark limestone with black chert nodules which, with its fossils, persists to the northeast limit of the formation northeast of Frenchburg, Menifee County. *Lithostrotion* is the most characteristic fossil of the St. Louis limestone at St. Louis and in the Mississippi Valley. In southeastern Illinois it is, so far as known, restricted to the St. Louis, and it is confidently believed that the limestone in central Kentucky, to which it is also restricted, is the same as the St. Louis. The lithologic character and stratigraphic relations—Warsaw below and Ste. Genevieve above—are equally strong evidence of the St. Louis age of the limestone here under consideration. In conclusion it is to be emphasized that the St. Louis is a very distinct lithologic unit, with definite and easily recognized upper and lower limits, which are not transgressed by most of the fossils occurring in itself nor by most of those occurring in the bounding formation.

Unconformity at Top of St. Louis Limestone.

There is, in some areas at least, a break marked by an erosional unconformity between the St. Louis and the overlying Ste. Genevieve. The most notable example of such a break is on Kentucky River about one-half mile east of Yellow Rock station, on the Louisville & Nashville Railroad and about 10 miles by railroad west of Beattyville, Lee County. A photograph of this unconformity is reproduced as Plate 56. A long stretch of the unconformable contact is shown in Plate 57. A detail of the basal Ste. Genevieve bowldery oolite immediately overlying the contact is illustrated by Plate 58. The characteristics of

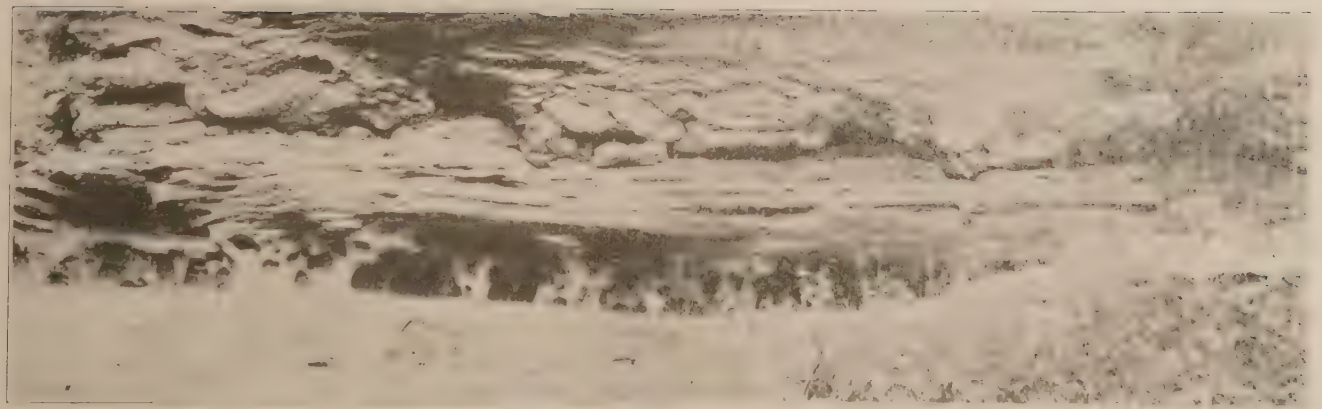


Plate 56. View of erosional unconformity between Ste. Genevieve and St. Louis limestones, Louisville & Nashville Railroad on Kentucky River about three miles west of Heidelberg. Short distance west of place shown in Plate 58. Looking north.

Plate 57. View looking west down Kentucky River from a point about one-half mile east of Yellow Rock station. Same unconformable contact as shown in Plate 56, between the light-colored bed at the bottom and darker bowldery bed of the Ste. Genevieve above shown in Plate 58. The prominent bedding contact next above is the persistent one between the bowldery bed and the thin-bedded or laminated upper siliceous oolite of the Ste. Genevieve. Top cherty bed of St. Louis with *Lithostration* absent in unconformity.

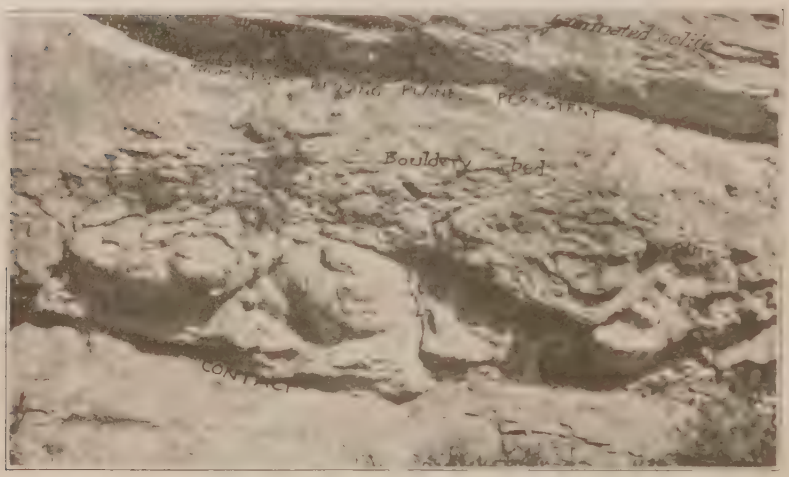


Plate 58. Bowldery oolite, basal bed of Ste. Genevieve oolite resting on St. Louis limestone with an erosional unconformity between. Louisville & Nashville Railroad on Kentucky River about three miles west of Heidelberg. Looking north. Cherty bed with *Lithostrotion*, forming the top member of the St. Louis generally in Eastern Kentucky, absent in the unconformity. See Plate 59.

this bed clearly indicate unusual conditions attending its deposition. Notwithstanding the irregularity of the top of the St. Louis here, the amount of erosion appears to have been slight. This conclusion rests on the fact that the bowldery bed of the Ste. Genevieve rests upon the yellow limestone of the lower part of the St. Louis, whereas at Irvine and elsewhere the bowldery bed rests upon an intervening bed of dark, cherty limestone, 10 feet or so thick, already described as the top member of the St. Louis. (See Plate 59.) At Irvine below the cherty limestone is about the same thickness of yellow limestone as there is below the unconformity on Kentucky river. At Olive Hill and Carter the bottom foot of the Ste. Genevieve is strongly conglomeratic, being full of limestone and chert pebbles, some of good size. This conglomerate rests upon the top of the New Providence, so that there is a break, through the absence of the Keokuk, Warsaw, and St. Louis, amounting to at least 800 feet, mainly limestone. The conglomerate and unconformity are shown in plates

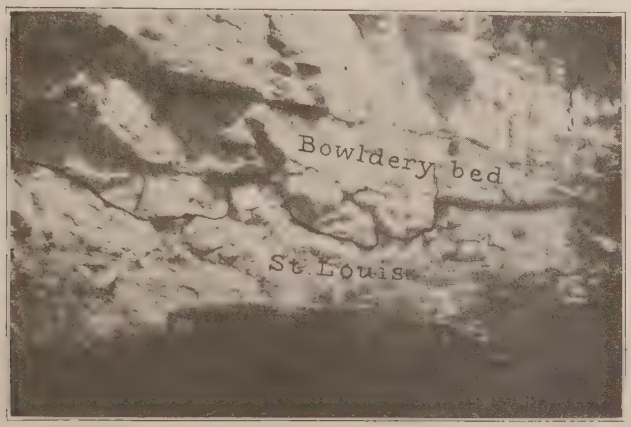


Plate 59. View showing irregular contact of the bowldery bed (see Plate 58) of Ste. Genevieve with the St. Louis limestone. The top six to eight feet of the St. Louis is a cherty limestone with ***Lithostrotion.*** This is underlain by about 20 feet of yellow limestone (not shown in the photograph) which rests on the New Providence formation. The ***Lithostrotion*** bed is absent in the unconformity shown in Plates 56, 57 and 58. Ridge about one-fourth mile north of top of Minerva Mountain, Irvine, Ky. Looking northeast.

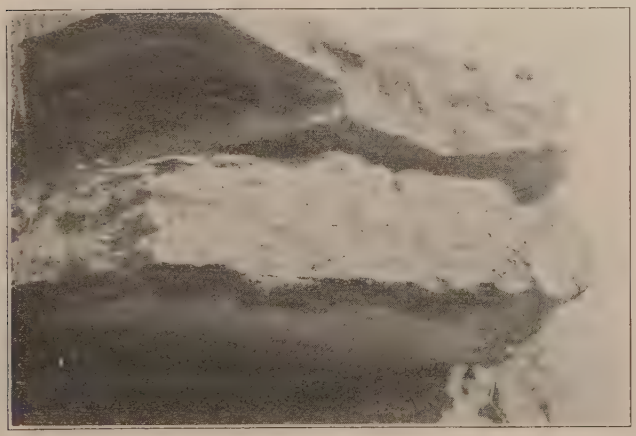


Plate 60. Basal conglomerate of the Ste. Genevieve in contact with the New Providence formation. Cut on Chesapeake & Ohio Railroad, one-half mile west of Olive Hill. Near View of basal bed shown in Plate 61.

Plate 61. Basal conglomerate of the Ste. Genevieve limestone underlain by New Providence shale and sandstone in cut just east of Olive Hill. Looking east. Keokuk, Warsaw and St. Louis absent, amounting to 800 feet.

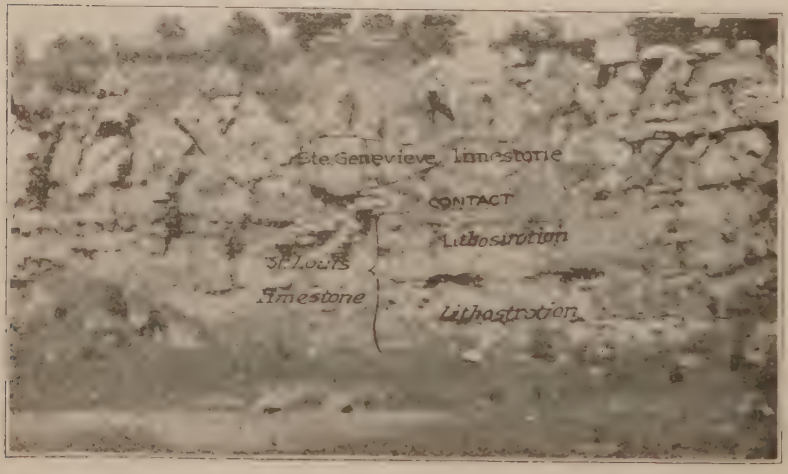


Plate 62. Old quarry one-half mile northwest of Somerset. Looking north. Ste. Genevieve limestone above. St. Louis below. Contact about middle. Layer with *Lithrostrotion proliferum* six feet below contact.

60 and 61. Such contact irregularities are not the usual thing, however. At Somerset and Burnside the contact is very regular as shown by Plates 62 and 63.

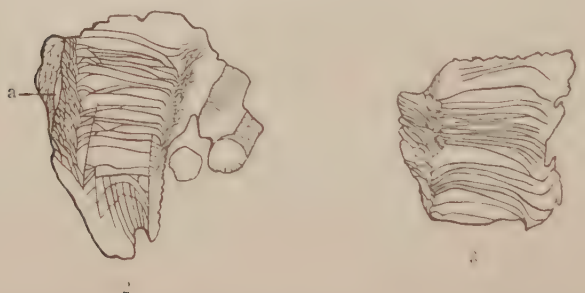
Another reason for believing that there is a break between the St. Louis and Ste. Genevieve is the presence of abundant angular fragments of black chert, evidently of clastic origin, in the basal 10 feet or so of the oolitic Ste. Genevieve throughout the region from Burnside, Pulaski County, to Mt. Vernon, Rockcastle County, a distance of 30 miles. The chert of these fragments is exactly like that of the nodules in the top cherty member of the St. Louis, and most probably that is its source. They

Plate 63. Natural exposure on Cincinnati Southern Railroad about one-half mile south of Burnside, Ky., showing Ste. Genevieve limestone above and St. Louis limestone below. Looking southwest. Contact at upper recess at base of massive bed. Nodules of black chert and Lithostrotion proliferum and L. canadense in the ten feet of limestone below recess.

are the smaller fragments of chert washed from the old St. Louis land surface tributary to the transgressing waters of the early Ste. Genevieve sea.

Another possible fact points strongly to an unconformity of even greater magnitude than indicated by the facts already related. It is possible that between the St. Louis and Ste. Genevieve, nearly throughout their entire extent, a certain thickness of limestone present locally at the base of

the Ste. Genevieve is absent. Reference is made to 50 feet or more of thin-bedded, gray, non-oolitic limestone which, along Ohio River in Hardin County, Ill., intervenes between the typical St. Louis and the typical oolitic Ste. Genevieve which everywhere, except in the locality named, rests directly upon the St. Louis. Those intermediate beds differ from the underlying St. Louis in their light gray color, in the absence, so far as known, of *Lithostrotion,* and in the presence of an abundance of *Platycrinus penicillus* (*huntsvillae*), which is extremely rare in the St. Louis, but common in the typical Ste. Genevieve. On the other hand, the intermediate beds differ from the typical Ste. Genevieve in their non-oolitic character. If the interpretation here tentatively advanced should be sustained by further observations, it would mean a time break of considerable length between the top of the St. Louis limestone and the base of the Ste. Genevieve limestone.



Figs. 2-3. Campophyllum gasperense n. sp. Natural size, pp. 162-164. Median longitudinal section showing wide tabulate visceral chamber and peripheral vesicular tissue; a, lumen between epithecae of adjacent coralites filled with oolitic matrix. Locality, Nettlecarrier Creek, 3 miles northeast of Livingston, Overton county, Tenn.

CHAPTER 6.

Ste. Genevieve Limestone

Name and Limits. The Ste. Genevieve limestone takes its name from the town of Ste. Genevieve, Mo., on Mississippi River, about 45 miles south of St. Louis. It was so named by Shumard[30] in 1857. In Mississippi Valley, the type locality of the Ste. Genevieve, it is limited below by the well differentiated St. Louis limestone and above by the Aux Vases sandstone, which by most authors is taken as the base of the Chester group. Not far below the Aux Vases sandstone is another thin sandstone in the Ste. Genevieve that appears to be at the horizon of the Rosiclare sandstone of Ohio Valley. (See Sec. No. 1, section chart.) Ulrich[31] included in the Ste. Genevieve certain beds (now known as "Upper Ohara") which in western Kentucky and southeastern Illinois seem to occupy a somewhat higher horizon than the top of the Ste. Genevieve of Mississippi Valley. These beds, together with that part of the typical Ste. Genevieve overlying the Rosiclare sandstone, were treated by Ulrich as a member (Ohara limestone member) of the Ste. Genevieve, which, with that addition, in wstern Kentucky extends from the St. Louis below to the Bethel sandstone above. The Bethel is regarded by Ulrich as the equivalent of the Aux Vases sandstone. He also treats the part of the Ste. Genevieve below the Rosiclare sandstone as a member, which he named the Fredonia oolite member. Further, he places the entire Ste. Genevieve in the Chester group. This arrangement is opposed by Weller. and their conflicting views are set forth in the publications named in the footnote[32]. The definition of Ste. Genevieve limestone being still in dispute, the limits set by Ulrich are followed in this report.

In western Kentucky the Bethel and Rosiclare sandstones have not been recognized east of Todd County, the Rosiclare in fact does not appear to extend east of Caldwell County. East

[30] Shumard, B. F., St. Louis Acad. Sci. Trans., Vol. 1, p. 406, 1857.
[31] Ulrich, E. O., U. S. Geol. Survey Prof. Paper 36, 1905.
[32] Ulrich, E. O., Mississippian Series of Western Kentucky, Part II, Kentucky Geol. Survey, 1917.
Weller, Stuart, and Butts, Charles, Geology of Hardin County, Illinois. Illinois Geol. Survey, 1921.

of Todd County, therefore, it is, without having learned certain criteria by experience, difficult to separate the Ste. Genevieve from the overlying Gasper oolite. However, there is nearly everywhere a shale or a sandy limestone or an argillaceous shaly limestone at the approximate horizon of the Bethel sandstone that serves as a lithologic boundary between the two oolites. (See sections of Plate 69 and photographs, Plates 70 to 78.)

Distribution. The Ste. Genevieve extends as a broad belt from Ohio River in western Meade County southward to the state line. The Louisville & Nashville Railroad is situated on

Plate 64. Point of a spur about four miles east of Berea, Ky., capped with limestone and Rockcastle conglomerate. Looking southwest. The Rockcastle here rests on the Gasper oolite, which corresponds nearly to the Maxville limestone of Ohio.

this belt the entire distance between Elizabethtown, Hardin County, and Woodburn, Warren County. Munfordsville, Glasgow Junction, and Bowling Green are located upon this belt. East of the Bluegrass region the Ste. Genevieve also occupies a narrow belt of outcrop from Tennessee to Ohio River. Monticello, Somerset, and Mt. Vernon are in part located upon it. Farther north it forms part of the limestone outcropping along the brow of the high escarpment facing west toward the Bluegrass region the greater part of which corresponds to the Maxville limestone of Ohio. (See Plates 10, 22, 64 and 65.)

Plate 65. Pilot Knob, about five miles northwest of Berea, Ky., capped by Gasper oolite and Ste. Genevieve limestone and probably by a thin residual of Rockcastle conglomerate. Looking northwest. Limestone corresponds nearly to the Maxville limestone of Ohio.

Plate 66. Ste. Genevieve limestone (Fredonia oolite member). Cut on Louisville & Nashville Railroad, one to two miles north of Munfordville, Hart County. Looking northwest.

Character. The Ste. Genevieve is mostly a thick-bedded oolite interbedded with which are layers of non-oolitic limestone. That is its character along its western outcrop. The thick layers weather white and at many points are conspicuous objects in the fields where the layers are exposed. The general appearance in this belt is well illustrated by the photograph, Plate 66. The section as it is in Sparks quarry, near Mt. Vernon,

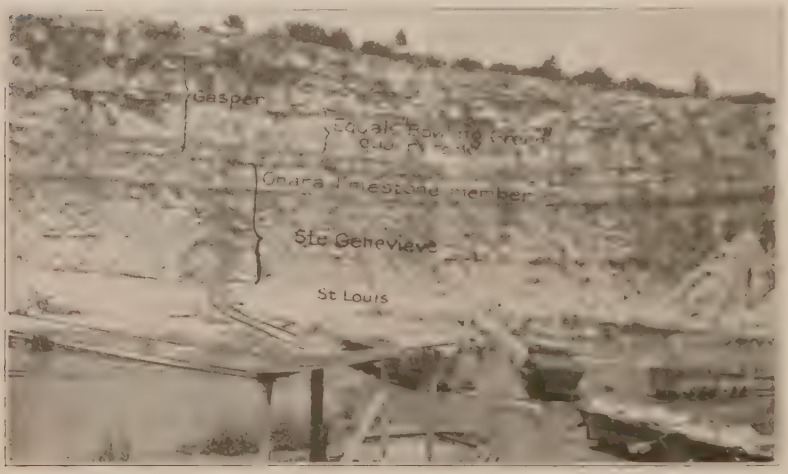


Plate 67. Quarry about three-fourths mile west of Mt. Vernon. Looking north. Ste. Genevieve and Gasper oolites, almost full thickness. Bottom of quarry on the top of the cherty St. Louis limestone. This photograph shows the lack of any lithologic difference between the Ste. Genevieve and Gasper, although about 200 feet of beds representing the Bethel sandstone and part of the Ohara limestone are absent between the two, being represented by only fourteen feet of Ohara limestone, with thin clay or thin cobbly limestone at top and bottom.

Rockcastle County, is representative for the outcrop from that place south to the state line.

Section of the Ste. Genevieve limestone and Gasper oolite at Sparks quarry, three-fourths of a mile west of Mt. Vernon. (See Plate 67.)

19.	Top of hill. Slabs of yellow limestone with *Archimedes*. This yellow limestone in the town of Mt. Vernon carries also *Agassizocrinus* and *Pentremites*. May be Golconda.	
Gasper oolite:		**Feet**
19.	Not exposed	10
18.	Limestone, blue crystalline. Large crinoid stems 20 feet below top. *Composita subquadrata* in bottom	43

17.	Limestone, compact, yellow, in two layers	5
16.	Oolite, blue, *Agassizocrinus, Girtycella, Composita*	2
15.	Oolite, compact, blue, banded	2
14.	Limestone, compact, brittle, blue, weathers yellow	1½
13.	Limestone, shelly, and shale, green, 6 inches to	1
12.	Oolite, coarse, white, *Pentremites pyriformis Talarocrinus*. Equivalent to "Bowling Green" quarry rock	17
	Total Gasper oolite	81½

Ste. Genevieve limestone:

Ohara(?) limestone member of Ste. Genevieve limestone:

11.	Limestone, light-blue, brittle. Top 2 feet seamed with calcite veins, appears brecciated, top 6 inches, conglomerate in yellow matrix. Hummocky top surface with depressions occupied with green shale	5
10.	Limestone coarse, light gray, slightly oolitic	5
9.	Oolite, dark or drab	4
	Total Ohara (?) about	14
8.	Cobbles and shale	½
7.	Limestone, compact, brittle, pearl gray	9
6.	Oolite, bluish gray, weathers white	9¾
5.	Oolite, coarse, cross-bedded, white	8½
4.	Limestone, dark, drabbish gray, thin layered or flaggy	3⅓
3.	Oolite, compact, white, some chalky texture. *Platycrinus penicillus* in this bed at Dick Owens cut, 1 mile farther west	5
2.	Limestone, compact, brittle, pearl gray, evenly-bedded flags	4
	Oolite, thickbedded, dark gray	5
	Oolite, drab gray with angular fragments of black chert	2½
	Total Ste. Genevieve limestone below Ohara(?) member	47 7-12

St. Louis limestone:

1.	Limestone, dark or drab, hummocky, sun-cracked surface, black chert nodules, exposed	1

Between Mt. Vernon and Berea the Ste. Genevieve undergoes a remarkable change. In all the sections examined to the east of Berea, Nos. 33 to 36 of the section chart, the Ste. Genevieve is almost wholly made up of very even thin layers about one-half inch thick. At the head of Owsley Branch a few specimens of *Platycrinus penicillus* (*huntsvillae*) were found in

a thicker layer of oolite having several feet of the thin layered oolite below, proving that the thin layered oolite is Ste. Genevieve. That is the most northerly point at which *Platycrinus* was found in the Ste. Genevieve. Between Owsley Branch and Irvine, a distance of a dozen miles or so, the Ste. Genevieve undergoes another equally interesting change. At Irvine and along Kentucky River to where the Ste. Genevieve goes under cover it is separated into two divisions by an unusually pronounced and persistent break of the apparent nature of an ordinary bedding plane. Below this bedding plane is about 10 or a dozen feet of thick-bedded and bowldery oolite. The bowldery character is very pronounced in places immediately above the unconformity between the St. Louis and Ste. Genevieve. Above the conspicuous bedding plane is thin layered oolite as already described. Both the divisions and the break between are shown in Plates 57, 58 and 59. A more important change perhaps is the introduction of small quartz pebbles into both divisions of the Ste. Genevieve. The pebbles are of the size of millet grains, and are well distributed through the mass. The quartz pebbles persist and become more abundant northeastward and at Limeville on Ohio River, 2 miles southeast of Sciotoville, Ohio, the Ste. Genevieve is so siliceous that it can only with difficulty be distinguished from Pottsville sandstone, which at one spot is in very irregular contact with it. A photograph, Plate 68, of a weathered surface of a layer of this siliceous oolite, exposed in a quarry at Carter, in Carter County, well illustrates its character. The pebbles here reach a size of one-eighth of an inch in diameter and seem to make up one-third to one-half of the bed. The matrix, however, is a gray oolite. In the Carter quarry the Ste. Genevieve has lost its thin-layered or laminated character and is thick to massively-bedded and of a peculiar greenish tinge in the mass effect of the quarry face. (See Plate 75.) At Pineville and Cumberland Gap the Ste. Genevieve is a thick-bedded gray oolite resembling more the character of the formation west of the Bluegrass region than that of the intermediate belt east of the Bluegrass region. At Big Stone Gap, Va., where the Ste. Genevieve forms the lower part of the Newman limestone, it is also largely thick-bedded gray oolite.

Plate 68. Face of a weathered layer of Ste. Genevieve limestone showing cross lamination and fine lamination parallel to bedding due to many thin laminae full of small quartz pebbles standing out on surface. Quarry one-half mile west of Carter, Kentucky.

Thickness. The Ste. Genevieve is about 160 feet thick in Meade County. No direct measurement of its thickness has been obtained in the western belt of outcrop, but in Barren County, the combined thickness of the Ste. Genevieve and Gasper is about 300 feet. As the thickness of the Gasper in that region is about 100 feet, it leaves about 200 feet for the Ste. Genevieve. On the eastern belt of outcrop the Ste. Genevieve, including the possible Ohara member, is 93 feet thick at Monticello, 75 feet at Burnside, 60 feet thick at Somerset, 60 feet at Mt. Vernon, about 45 feet two miles east of Berea, about 55 feet on the head of Owsley Branch, and 20 to 25 feet at Irvine. From Irvine northeastward it holds a nearly constant thickness of 20 to 25 feet, except at Carter quarry where it is 60 feet thick. At Limeville, Ky., 2 miles southeast of Sciotoville, Ohio, the most northern point in Kentucky that the Ste. Genevieve is present and exposed, it is 20 feet thick. At Pineville and Cumberland

Gap, where the boundary between the Gasper and Ste. Genevieve has not been satisfactorily located, the Ste. Genevieve is believed to be 80 to 100 feet thick.

Uses of the Ste. Genevieve Limestone. The oolitic beds of the Ste. Genevieve are of high purity and are suitable for lime and cement manufacture. This statement is based on the quality of the formation in Meade and Breckinridge counties, where its quality has been determined by analysis. The limestone for the Kosmosdale cement works in Jefferson County is obtained from the Ste. Genevieve in Meade County. Here the quarry rock of the face, about 100 feet in thickness averages about 95 per cent. calcium carbonate. The purer white oolite layers will probably average still higher in calcium carbonate. As the Ste. Genevieve holds the same appearance and proportionate amount of oolite all along its outcrop south into Simpson County, it is believed that its quality is at least as good throughout that belt as it is in Meade County. There are many points easily accessible to railroad where the topography is favorable for quarrying large bodies of the limestone without a prohibitive amount of stripping. The quality of the limestone along the eastern belt of outcrop is not so well known but, judging from the appearance of the rock, much of it, and especially the layers or gray oolite such as Nos. 3, 5 and 6, of the section, page 141, are as good as similar layers in the western belt. However, north of Mt. Vernon, where the Ste. Genevieve changes to a laminated oolite with quartz grains as described, pp. 141-142, it is worthless for any purpose except ballast, concrete, and road metal. It is quarried for such purposes at Olive Hill and Carter, Carter County, and at Mt. Vernon, Mullins, and Sparks Hill in Rockcastle County. At all these places it is quarried in conjunction with Gasper oolite to be described. (See Plate 67.)

Ohara Limestone Member. The origin and significance of the name Ohara have been set forth in the discussion of the name and limits of the Ste. Genevieve on pp. 137. It is believed that the Ohara is represented in eastern Kentucky and northern middle Tennessee in the upper part of the Ste. Genevieve. Beginning at Livingston, Overton County, Tenn., and extending as far north as Carter, Carter County, Ky., is a thin limestone set off above and below by thin but persistent layers

of shale or shaly limestone at places accompanied by thin limestone conglomerates or by limestone cobbles of small size. The facts are fully exhibited in the sections of Plate 69 and in the photographs, Plates 70 to 78. The lower shale or shaly limestone is generally thinner and less conspicuous than the upper. At Livingston, Tenn., Plate 70, this lower shale is 1 to 2 feet thick and above it is a layer of limestone conglomerate 1 foot

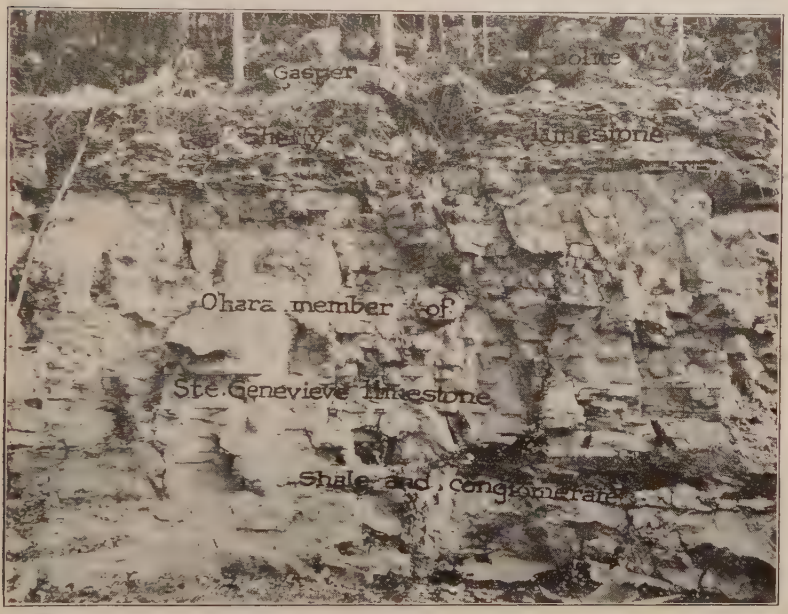


Plate 70. View in a quarry about one-fourth mile southeast of Livingston, Overton County, Tennessee. Shows bed of shelly limestone five feet thick underlying typical Gasper oolite; thick-bedded oolite about fifteen feet thick, with ***Talarocrinus*** plates, possibly representing Ohara limestone; and a shale one to two feet thick overlain by about one foot of limestone conglomerate below Ohara; and typical Ste. Genevieve (Fredonia) oolite with ***Platycrinus penicillus (huntsvillae)*** at bottom. This sequence is persistent northward along the west face of the Cumberland Plateau to Ohio River and affords the means of separating the Fredonia from the Gasper oolite.

thick. At Cedar Grove, 4 miles south of Somerset, Ky., this lower bed is an argillaceous limestone weathering to clay, and has a banded conglomerate layer below it. Here, the lower bed is thicker and more conspicuous than the upper. (See Plate 71.) The same sequence is exposed in a cut on the railroad 1 mile north of Cedar Grove but being comparatively fresh the shaly

Plate 71. Cut on Cincinnati Southern Railroad one-fourth mile south of Cedar Grove and four miles south of Somerset, Ky. Looking south. Shows near top an upper layer weathering to clay, a lower layer weathering to clay, and a layer of oolite between. Beds below the lower clay are Ste. Genevieve (Fredonia oolite member) with *Platycrinus penicillus (huntsvillae)* to the top. One-half mile north the oolite bed between the two clay layers is crowded with small specimens of *Pentremites princetonensis*; and *Mesoblastus glaber* are common and one or more species of *Talarocrinus* are present but not common. Invariable succession from Fredonia oolite to Gasper oolite along Cumberland escarpment. See Plates 70 to 78 inclusive.

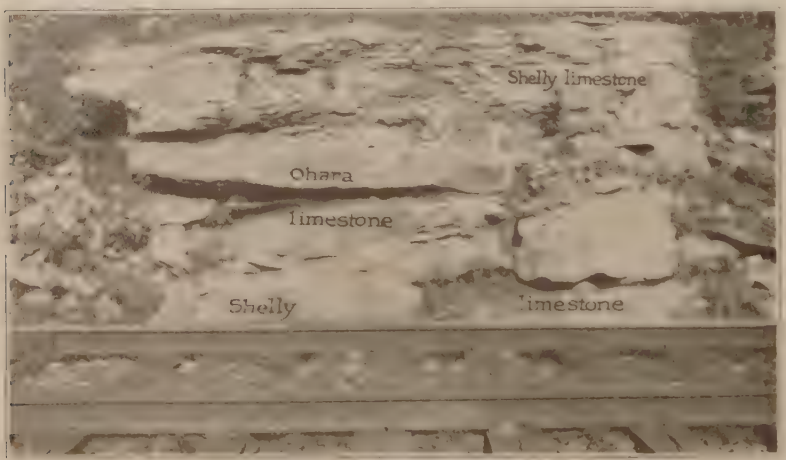


Plate 72. Cut on Cincinnati Southern Railroad about midway between Elihu and Cedar Grove and three miles south of Somerset, Ky. Shows the shelly limestone layer at the base of the Gasper, at top. This corresponds to the upper bed of clay in the cut one-fourth mile south of Cedar Grove. (Plate 71.) Oolite layer with Pentremites princetonensis, etc., below. Looking east.

Plate 73. Cut on Louisville & Nashville R. R. on Kentucky River about 2 miles west of Heidelberg. At bottom, argillaceous, gray, shelly limestone at base of Gasper oolite. Looking east.

Plate 74. Quarry in Ste. Genevieve and Gasper oolites. About three-fourths of a mile east of Olive Hill. The persistent shaly limestone or clay beds at the top of the Ste. Genevieve present here.

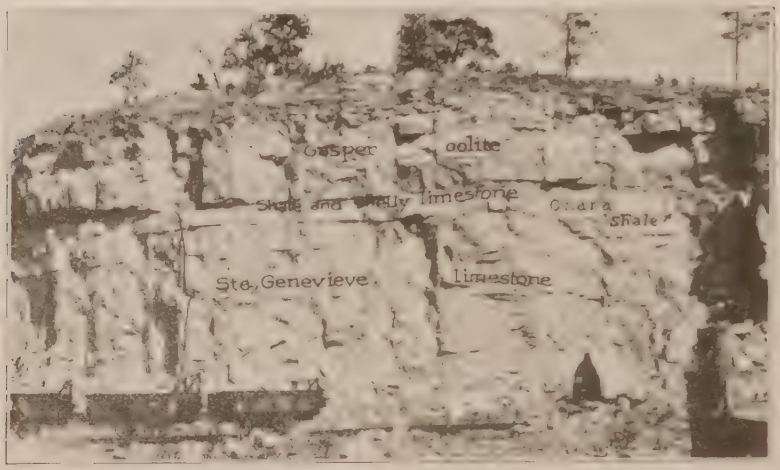


Plate 75. Quarry one-half mile west of Carter, Carter County. Looking north Ste. Genevieve limestone and Gasper oolite. The succession from the base up is limestone full of small quartz pebbles, shale, limestone, shale, thick-bedded Gasper oolite, and thin-bedded dark limestone at top of quarry face. Green shale overlain by massive limestone above top of face. The yellow layers of the Gasper and the gray layer between are very distinct. Lower yellow layer with *Martinia contracta* The limestone here is probably a thickened representative of the Maxville limestone of Ohio.

beds preserve their natural condition and have not disintegrated to clay as they do in some places where they have been subject to long continued weathering. (See Plate 72.)

The upper shaly bed is almost everywhere an argillaceous shelly limestone weathering white or rusty, dirty white. Under favorable conditions this bed is conspicuous in outcrop and markedly different from the thick-bedded oolite and limestone immediately above and below. A locality where this white layer is well displayed is in the fields on the northwest end of Wray Hill, one-half mile south of Monticello, Wayne County. Here it can be easily traced along the hillside nearly on the 1,100-foot contour for a distance of half a mile. The shaly layers and the intervening heavy limestone as exhibited at other localities are illustrated in Plates 73 to 76 inclusive. Only the upper shaly layer is shown in No. 73.

Between the two shaly layers described above is a persistent thick-bedded to massive limestone and oolite, generally 5 to 10 feet thick, but at Grundy, about 7 miles northeast of

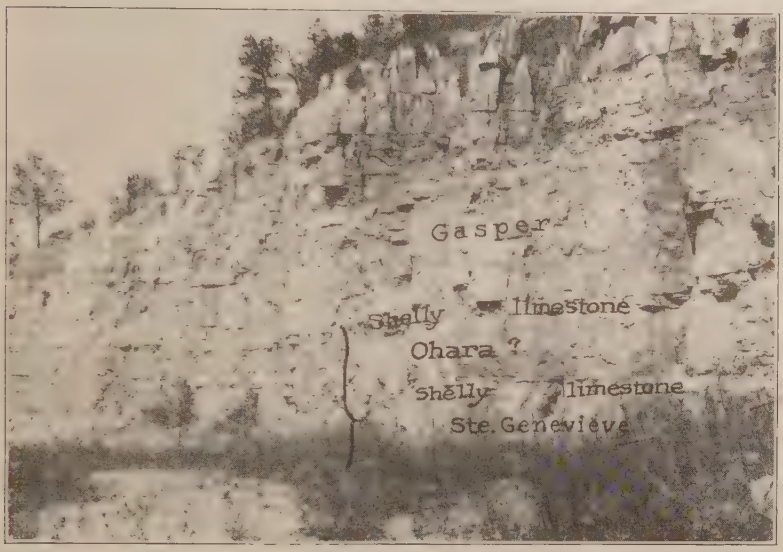


Plate 76. Quarry in Gasper oolite (above). About 1 mile south of Dividing Ridge, a station on the Louisville & Nashville Railroad about 5 miles north of Munfordville. Looking northeast.

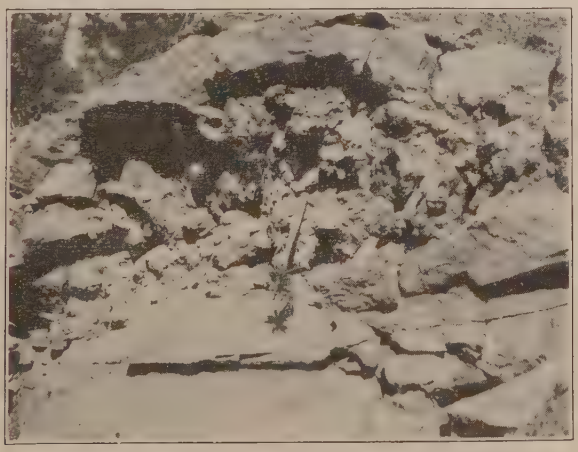


Plate 77. Nodular limestone layer between Ste. Genevieve and Gasper oolites. Old quarry one-half mile west of Carter, Ky.

Somerset, reaching a thickness of 40 feet. (Sec. No. 4, Pl. 69.) This limestone with the shaly layers above and below was recognized from Overton County, Tenn., to Mt. Vernon, Ky., and possibly on the head of Owsley Branch, east of Berea, but from that point north to Olive Hill, Carter County, it was not recognized, but only one shaly or cobbly layer between a thin Ste. Genevieve and a thin Gasper was observed. At Olive Hill and Carter the full sequence lower shaly layer, limestone member, and upper shale or shaly layer are present. (See photographs, Plates 74 and 75.) At Carter the limestone member is

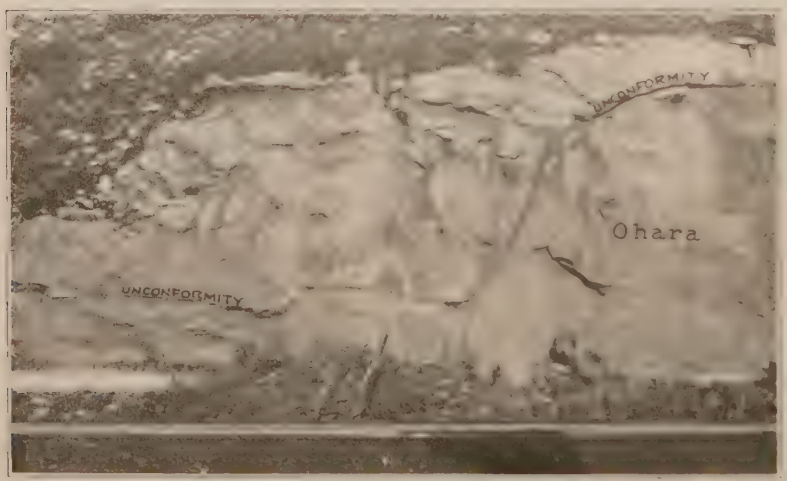


Plate 78. Cut on Cincinnati Southern Railroad between Elihu and Cedar Grove, 3 miles south of Somerset. Shows the shelly limestone layer at base of Gasper in unconformable contact on the oolite layer with *Pentremites*, *Mesoblastus*, and *Talarocrinus*. Looking east.

variable in thickness. It is mainly a light gray brittle limestone full of calcite veins, such as occur elsewhere at the same horizon. This layer thins out in the quarry face and on its thin edge takes on a bowldery form. (See photograph, Plate 77.) A layer of similar character occurs at Limeville, Ky., on Ohio River, 2 miles southeast of Sciotoville, Ohio, at the top of the Ste. Genevieve. In places there is an erosional unconformity between the limestone member and the overlying shaly bed. Such a place is on the Cincinnati Southern Railroad about

midway between Elihu and Cedar Grove south of Somerset. This unconformity is exhibited in the photograph, Plate 78.

It is believed that the limestone between the two shaly members in the persistent sequence just described represents the "Upper Ohara" part of the Ste. Genevieve of western Kentucky. More convincing evidence for that belief is stated under the next head.

Fossils and Correlation. The Ste. Genevieve is a fairly fossiliferous formation and considerable collections have been made. It seems to be rather more fossiliferous in Overton County, Tenn., than in Kentucky, and better collections were obtained in Overton County. These collections have not been fully identified but a few of the most diagnostic forms are common to abundant and are easily recognized. They are listed below:

LIST NO. 38.

Composite list of fossils from the Ste. Genevieve limestone collected mainly in Overton County, Tenn., on the southwestern extension of the eastern belt of outcrop of the Ste. Genevieve from Wayne and Clinton Counties, Ky.

Cystelasma quinqueseptatum Ulrich.
Lithostrotion harmodites E. & H. abundant.
Michelinia princetonensis Ulrich.
Michelinia subramosa Ulrich.
Dizygocrinus supersetes Ulrich?
Pentremites princetonensis Ulrich rare.
Platycrinus penicillus Worthen. Equals P. *huntsvillae* Wachsmuth Springer.
Diaphragnus sp.? rare.
Composita trinucelea (Hall)
Dielasma illinoisensis Weller.
Eumetria verneuiliana (Hall).
Girtyella indianensis (Girty).
Orthotetes kaskaskiensis (McChesney).
Productus ovatus Hall.
Productus parvus Meek and Worthen.
Pugnoides ottumwa (White).
Pustula genevievensis (Weller).
Spirifer pellaensis Weller.
Myalina sancti-ludovici Worthen.
Bellerophon sublaevis Hall.

The species of this list down to and including *Platycrinus penicillus* and also *Pugnoides ottumwa* are widely distributed species and so far as known are restricted to the Ste. Genevieve limestone, so that their presence in the limestone of middle Tennessee and central Kentucky here under description shows that it is beyond a doubt the Ste. Genevieve. *Lithostrotion harmodites* is extremely abundant in Overton County, Tenn., but less plentiful in central Kentucky. It occurs at the old quarry at Richardson's landing, in Meade County, where it comes in at the very top of the Ste. Genevieve. At Mystic, in Breckinridge County, it is rather plentiful at two horizons within 50 feet of the top of the Ste. Genevieve. It is abundant at Grundy, Pulaski County, 7 miles northeast of Somerset, in the top of a layer just beneath the shale underlying the Ohara member. It occurs, too, at Pineville, in the southeastern part of the state, so that it ranges the entire length of Kentucky.

Platycrinus penicillus, more commonly known as *Platycrinus huntsvillae*, is the Ste. Genevieve guide fossil par excellence, being abundant in most of Kentucky west of the Bluegrass region, and through Tennessee to Huntsville, Ala., from which it takes the name *huntsvillae*. In the belt east of the Bluegrass region it is scarce at Mt. Vernon and northward. It is present near the bottom of the Ste. Genevieve at the head of Owsley Branch, 8 miles east of Berea, but was not seen north of that locality. Indeed at Irvine and northward, where the Ste. Genevieve is full of fine quartz pebbles, it seems to be practically non-fossiliferous. *Platycrinus* occurs, too, at Cumberland Gap and as far north as Big Stone Gap, in limestone and oolite of strictly Ste. Genevieve character in the Newman limestone, so that there is no doubt that a hundred feet or so of the Newman limestone is equivalent to the Ste. Genevieve.

The limestone believed to represent the Ohara member of the Ste. Genevieve is very fossiliferous along the Cincinnati Southern Railroad between Elihu and Cedar Grove. Judging from the numbers on the weathered surface of the limestone, it must in this region hold literally millions of individuals of *Pentremites princetonensis* and many specimens of a few other forms named in the following list:

List of fossils from the Ohara limestone member between Elihu and Cedar Grove on the Cincinnati Southern Railroad South of Somerset, Ky.

Dizygocrinus persculptus Ulrich, rare.
Mesoblastus glaber Meek and Worthen, common.
Penetremites princetonensis Ulrich, very abundant.
Pentremites pulchellus Ulrich.
Talarocrinus buttsi Ulrich, rare.
Talarocrinus dewolfi, Ulrich? fairly common.
Talarocrinus n. sp.? conical base but not so pointed as *T. buttsi*, fairly common.
Diaphragmus monte sana Ulrich? rare.

In the interpretation of the fossils and stratigraphic circumstances of the limestone (Ohara) here under consideration, it will be necessary to recall the section of the Ste. Genevieve in western Kentucky, as illustrated in Sec. No. 1, section chart. In western Kentucky the Ste. Genevieve is divided into 3 members, the Fredonia oolite below, the Rosiclare sandstone, and the Ohara limestone above. Also, above the Rosiclare is about 30 feet of thick-bedded oolite like the Fredonia, while the upper part of the Ohara presents constant differences of lithology and fossils. These parts are designated "Lower Ohara" and "Upper Ohara" respectively. Between the "Lower" and "Upper Ohara" is in places at least a limestone conglomerate. Now in the Fredonia and "Lower Ohara" *Platycrinus penicillus (huntsvillae)* is a common and distinctive fossil. In eastern Kentucky, where the Rosiclare sandstone is absent, *Platycrinus penicillus* occurs up to the shaly layer underlying the limestone here under description, but with careful search in several localities the writer was unable to discover a single specimen in this limestone. Again, Talarocrinus is unknown in the Fredonia and, so far as known to the writer, in the "Lower Ohara" also. Such circumstances seem clearly to exclude the limestone under consideration from the Fredonia and "Lower Ohara." On the other hand such forms as *Pentremites pulchellus* and the species of *Talarocrinus* listed are not known above the "Upper Ohara" and the species of *Talarocrinus* listed seem confined to it. The evidence, therefore, seems sufficient to warrant assigning the limestone between the two shaly beds to the "Upper Ohara."

It is possible that the upper shaly bed is the material deposited in eastern Kentucky while the Bethel sandstone, between the Ohara and Gasper, was being laid down in western Kentucky.

As regards the grouping of the Ste. Genevieve, there is a difference of opinion between the two main authorities, Ulrich and Weller. Ulrich includes it in the Chester group, Weller in the Meramec group. Ulrich has shown that the Ste. Genevieve has more fossils tending to tie it to the Gasper oolite than it has tending to relate it to the St. Louis limestone of the Meramec group. That fact, combined with at least local unconformities at the base of the Ste. Genevieve, if not a general unconformity, as described on pp. 129-137, and the further that it is lithologically identical in character with the overlying Gasper oolite, both being predominantly thick bedded gray oolite, while the St. Louis limestone of the Meramec group is a fine-grained, mostly dark limestone without oolite, seem to the writer to show that the natural relations of the Ste. Genevieve are with the Chester rather than with the Meramec group. This view is strongly supported in regions where, as along the western escarpment of the Cumberland Plateau from Huntsville, Ala., to the Ohio River, the Bethel sandstone is absent and the Ste. Genevieve and Gasper form a continuous vertical succession. After examining the various sections of the section chart through the Ste. Genevieve and Gasper, and examining the photographs of Plates 67, 74, 75 and 77, the proposition to classify the Ste. Genevieve and the Gasper in separate groups seems untenable to the writer. The disposition would be to unite the two into a single formation, as was done essentially by Ulrich. He united the Ste. Genevieve, Bethel sandstone, and Gasper ("Tribune") into a group which he named the "Monte Sana Group," from Monte Sana, near Huntsville, Ala. Where the Bethel sandstone is absent, however, as along the western Cumberland escarpment, the Ste. Genevieve and Gasper constitute essentially one lithologic unit.

Relation of the Ste. Genevieve to the Maxville Limestone of Ohio. The Maxville limestone of Ohio has been correlated by Weller and Foerste with the Ste. Genevieve, by the last-named with the Ohara member.[33] Others, as Andrews, Meek and Whittield, have believed that the Maxville is Chester and possibly, in part, St. Louis.[34]

Ulrich[35] has more recently correlated the Maxville with the Gasper oolite. It appears from the writer's work that Ulrich is in the main correct. If the Ste. Genevieve extends into Ohio, it is either in areas detached from the main body of the Maxville, as in Kentucky at Limeville, or if present in any of the Maxville areas it is a thin unfossiliferous basal layer and not represented in the Maxville fauna. It is probable indeed that the Ste. Genevieve extends beneath southeastern Ohio as a basal member of the Maxville limestone (Big lime of the oil well drillers), and reappears in southwestern Pennslyvania on the Chestnut Ridge anticline as the Loyalhanna "Siliceous" limestone of Pennsylvania, which there rests upon the Burgoon sandstone (Pocono, Big Injun sand), which is the equivalent of the Logan formation, which immediately underlies the Ste. Genevieve limestone of northeastern Kentucky. The Loyalhanna limestone underlies the Greenbrier limestone of southwestern Pennsylvania and western Maryland, which in turn is correlated with the Gasper which overlies the Ste. Genevieve in northeastern Kentucky. The Loyalhanna limestone, too, in some of its phases, closely simulates such phases of the Ste. Genevieve as that shown in Plate 68. Taken altogether the circumstances afford fair grounds for correlating the Loyalhanna limestone with the Ste. Genevieve.

The author in a former publication expressed the opinion that the Loyalhanna is to be correlated with the Warsaw, because both are crossbedded siliceous limestones, and because at that time the Burgoon sandstone was supposed to be of Keokuk (Fort Payne) age, and if that had been correct the Loyalhanna would

[33] Personal communication to Wm. C. Morse. The Maxville limestone. Geol. Survey of Ohio, Bull. 13, Fourth Series, footnote, p. 108.
[34] Morse, Wm. C., op. cit.
[35] Ulrich, E. O., Mississippian Series in western Kentucky, Pt. II, p. 5 and Plate B, 1917.

then be in normal sequence for the Warsaw. However, in view of the fact that the Warsaw wedges out in southeastern Kentucky, its correlation with the Loyalhanna must be abandoned.

Figs. 4-6: Campophyllum gasperense, n. sp. calycinal views, natural size, pp. 162-164. 4. Largest specimens in collections; upper part of calycinal wall broken away, has a few secondary septae. Locality, Brandon Station, Ala., 60 miles southwest of Chattanooga, Tenn. 5. Nearly perfect calice about 3/8 inch deep; no secondary septae, usual condition. Locality about 4 miles west of Bowling Green, Ky. 6. Specimen preserving secondary septae. Locality near Cedar Grove, 4 miles south of Somerset, Ky.

CHAPTER 7.

CHESTER GROUP

Name and Limits. The Gasper oolite was named by Butts[36] in 1917, from Gasper River, in the western part of Warren County, Ky. The lower boundary of the Gasper has been already described in connection with the Ste. Genevieve limestone. Strictly speaking, if the shaly layer above the Ohara member is the equivalent of the Bethel sandstone, as surmised, the bottom of the Gasper is at its top. In practice, however, the top of the Ohara member is taken as the bottom of the Gasper. In the western belt of outcrop, in Meade and Breckinridge counties, and perhaps farther south, the Gasper, owing to the absence of the Ohara, rests upon some lower part of the Ste. Genevieve. In an old quarry at Richardson's landing, in Meade County, the Gasper rests on layers of white limestone with *Lithostrotion harmodies.* These *Lithostrotion* bearing layers are certainly below the horizon of the Rosiclare sandstone member, and so in the Fredonia oolite, the entire Ohara being absent. Here there is an unconformity at the base of the Gasper measured by the Ohara limestone member and Bethel sandstone, amounting to 200 feet. In the type locality of the Gasper, however, in the western part of Warren County the Ohara is believed to be present, and consists of about 40 feet of thick-bedded limestone. Along the entire western belt of outcrop between Meade and Warren counties the Gasper is bounded above by the Cypress sandstone, and the Cypress forms the upper boundary probably in Clinton County and in the southern part of Wayne County but in most of Wayne County and north to Carter County the top of the Gasper is supposed to be a few feet below a persistent green, marly shale bed, in Kentucky about 10 feet thick. The shale is certainly the same as a shale above the Cypress sandstone in Overton County, Tenn., regarded as representing the Golconda formation of western Kentucky. (See Sec. No. 1 of section chart.) A few feet of limestone included in the top of the Gasper is also regarded as Gol-

[36] Butts, Charles, Mississippian formations in Western Kentucky, Part I, page 64, 1917.

conda, the Cypress sandstone horizon being believed to lie below this limestone and about 10 feet below the persistent shale bed. The position of this shale is everywhere marked on the slopes by a narrow but perfectly distinct and easily recognized terrace, along which in Tennessee roads and paths are located in many places. For all practical purposes this terrace may be taken to mark the top of the Gasper in eastern Kentucky. Evidences of the shale in the form of green or red clay is usually obvious on this terrace or can be detected by a short search.

Distribution. The Gasper oolite outcrops continuously along both the east and west sides of the Bluegrass region but the two belts are nowhere connected, although the Gasper is present in the knobs across Hart County and in Green River Knob in the south corner of Casey County. It probably is not present in Green, Taylor, Adair, Metcalfe, Allen, Monroe, or Cumberland counties, although there may be some knobs high enough to catch it in the southeastern part of Cumberland County. The eastern belt extends along the western escarpment of the Kentucky coal fields in Kentucky and of the Cumberland Plateau in middle Tennessee into Alabama. The western belt is continuous from Ohio River in western Meade County, through the intermediate counties to central Warren County. It makes the face of the escarpment or bluff about 2 to 5 miles northwest of the Louisville & Nashville Railroad and visible therefrom all the way from Munfordville to Bowling Green. Along its eastern outcrop it is the principal component of the limestone cliff so conspicuous from Rockcastle county to Powell county near the top of the escarpment bounding the coal field. (See photos, Plates 22, 64 and 65.) The Gasper continues north into Ohio but does not extend as far west in Carter County as does the underlying Ste. Genevieve. The Gasper extends beneath the eastern Kentucky coal field as a part of the Big Lime, and reappears at Pineville and Cumberland Gap, where it makes up about the upper half of the lower half of the Newman limestone.

Character. As indicated in the name, the Gasper is mostly an oolitic, somewhat crinoidal limestone, but has a little shale. In general it does not differ in any important lithologic character from the underlying Ste. Genevieve limestone or oolite.

except possibly in its tendency to develop yellow layers in places, as in the vicinity of Mt. Vernon, Rockcastle County and of Carter, Carter County. A good general notion of its character can be had from an inspection of the written section of Sparks quarry, near Mt. Vernon, in the description of the Ste. Genevieve, pp. 140-141, also in the Gasper section of the same quarry, No. 5, Plate 69, and other sections as Nos. 5, 12, 13, 19, 23, 38 and 41 of thte general section chart.

The Gasper is nearly all thick bedded throughout its extent and light gray or bluish gray. At Olive Hill and Carter, Carter County, as shown in the quarries at those places, however, it is largely made up of massive layers of yellow oolitic limestone. Even here it has conspicuous layers of light gray oolite. (See Plates 74 and 75.) A notable feature of the Gasper is an apparently universally persistent thick bed of light gray oolite in the lower part that is of the character and occupies the position of the "Bowling Green oolite," a high-class building stone in Warren County. This bed is No. 12 of the written section, p. 141, and is well-shown in the photograph of Sparks quarry, Plate 67. Plate 77 is a photograph showing the general appearance of the Gasper in its western outcrop.

Economic Uses. The Gasper oolite probably is of as good quality as the Ste. Genevieve, and would be equally suitable for lime and cement manufacture. At Olive Hill, Carter County, it is reported to include layers averaging 98 per cent. of calcium carbonate. It is not at present utilized for such purposes but is quarried in the vicinity of Mt. Vernon, Rockcastle County, and Olive Hill and Carter, Carter County, for ballast and road metal.

Thickness. Along its western outcrop the Gasper is about 100 feet thick. On the eastern outcrop it is thickest in the south and thins gradually northward. At Monticello, Wayne County, it is 134 feet thick, at Mt. Vernon, Rockcastle County, it is 95 feet thick; at Irvine 50 feet thick, on Morris Mountain, Powell County, about 40 feet thick, at Olive Hill about 45 feet, and at Carter, Carter County, 27 to 30 feet. Where the Sample sandstone member reaches its greatest thickness, in Breckinridge county, the Gasper is 140 feet thick.

Sample Sandstone Member. In Breckinridge and Meade counties a sandstone of variable thickness occupies the middle of the Gasper. It was named by Butts[37] in 1917 from Sample, Breckinridge County, a small station on the Louisville, Henderson and St. Louis Railroad.

The Sample sandstone is a rather prominent member throughout Breckinridge County, where its horizon has escaped erosion. It varies greatly in thickness in short distances, in places being thin and shaly and less than one mile away being a massive sandstone 40 feet thick. It thins southward and near Eastview, on the Illinois Central Railroad, is represented by about 20 feet of shale with thin sandstone layers in the middle. Southwestward and westward to Caldwell County the Sample member is represented by a persistent clay up to 5 feet thick in the midst of the Gasper. The horizon of the Sample sandstone member is not indicated in the Gasper east of the Bluegrass region.

Fossils and Correlation. The Gasper in eastern Kentucky does not yield many fossils either of individuals or species. It does, however, carry some highly distinctive forms which are believed to be confined to it. A list is given below for both the eastern and western areas:

LIST NO. 39.

Partial List of Fossils from the Gasper Oolite of Eastren and Central Kentucky.

Campophyllum gasperense n. sp. Butts, branching coral.
Large crinoid stem up to nearly 1 inch in diameter not known in any other Chester formation.
Pentremites godoni De France.
Pentremites planus Ulrich.
Pentremites pyriformis Say. Most common and persistent fossil of the Gasper.
Pentremites symmetricus Hall.
Pentremites welleri Ulrich.
Agassizocrinus sp.?
Talarocrinus delicatulus Ulrich.
Talarocrinus elegans Lyon and Casseday.
Talarocrinus ovatus Worthen.

[37] Butts, Charles, The Mississippian formations of western Kentucky. Kentucky Geol. Survey, p. 70, 1917.

Talarocrinus patei Miller and Gurley.
Talarocrinus sexlobatus (Shumard).
Talarocrinus symmetricus Lyon and Casseday.
Archimedes laxus Hall.
Archimedes terbriformis Ulrich.
Archimedes swallowanus Ulrich?
Chonetes chesterensis Weller.
Diaphragnus elegans (Shumard).
Diaphragnus monte sana Ulrich?
Girtyella indianensis (Girty).
Martinia contracta Meek and Worthen.
Productus inflatus McChesney.
Productus ovatus Hall.
Spirifer leidyi Hall.
Bellerophon subaevis Hall?

The forms important for correlation in this list are the big crinoid stems, the branching coral, and the species of *Pentremites*, *Talarocrinus*, and the *Martinia*. The listed spieces of all these genera are all or nearly all present in the type locality of the Gasper. The species of *Talarocrinus* named do not occur outside of the Gasper. Indeed the genus does not appear to range above the Gasper, no instance of its occurrence above being on record so far as the writer is aware. All the species of *Talarocrinus* listed occur on the eastern outcrop of the Gasper, some of them at least as far north as Kentucky River, and a single base of an apparently different species was obtained from the quarry at Olive Hill, Carter County. Species of *Talarocrinus* occur at Big Stone Gap, Va., in oolite somewhat below the middle of the Newman limestone. The *Pentremites*, especially the species *godoni*, *planus* and *pyriformis*, are equally characteristic of the Gasper in both of its areas of outcrop. The first two named species are absent or scarce north of Somerset, but *Pentremites pyriformis* is persistent and fairly plentiful throughout the entire extent of the Gasper, even into southwestern Virginia. It is rather plentiful at Carter, Carter County, in association with *Martinia contracta*, and is recorded from the Maxville limestone of Ohio. *Campophyllum gasperense* is another charasteristic fossil of the lower part of the Gasper. It is reported by Ulrich from Caldwell county, Ky., is present in the northwestern part of Warren County, the type locality of the

Gasper, at Smiths Grove, Warren County, and at Sample, Breckinridge County. It occurs in myriads near Cowan, Franklin County, Tenn., in association with the Gasper Pentremites, and has been collected along the eastern belt of the Gasper, as far north as Somerset, Ky., invariably within 20 to 30 feet of the bottom of the Gasper. It is common at the north end of Lookout Mt., Tenn. and at Big Stone Gap, Va. where its horizon is also about 30 feet above the botton of the Gasper. This species is described below. The big crinoid stems are also invariably present in the upper part of the Gasper from Overton county, Tenn., to Carter, Carter county, Ky. Its general position is about 20 to 30 feet below the top.

The stratigraphic relations, lithologic character, and fossils prove beyond a doubt the identity of the Gasper throughout eastern Kentucky, and carry it into Ohio as the main fossiliferous part of the Maxville limestone, as concluded by Ulrich in 1917.[38]

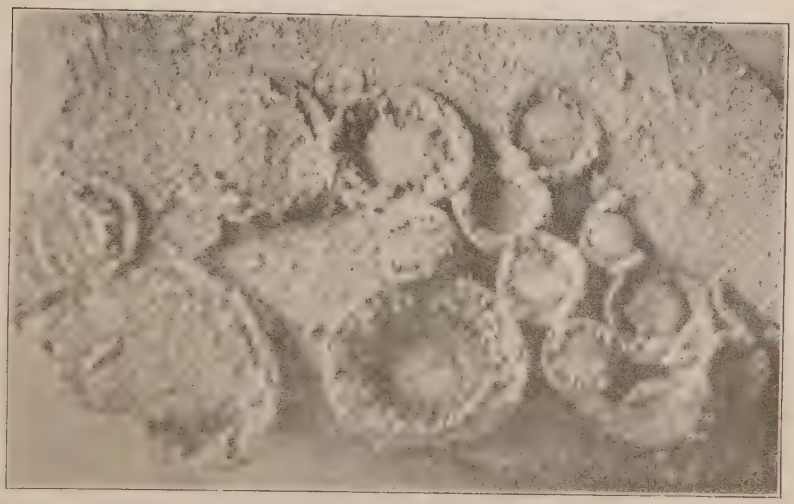
CAMPOPHYLLUM GASPERENSE n. sp. Butts. Plates 78 A-D. Also p. 136 figs. 2-3, and p. 156 figs. 4-6.

Corrallum composite, coralites cylindrical, slightly tapering. In contact tangentially or free, generally the former. Epitheca wrinkled. Increase mainly by calycinal gemmation, as many as a dozen coralites being given off at one circlet.

The largest specimen observed is 32 millimeters in diameter at the top of the calice. A specimen about 50 mm. long is 12 mm. in diameter at the distal end which would indicate a length of 150 mm. for the largest specimen. Calice deep. In a specimen 15 mm. in diameter it is 10 mm. deep with perpendicular inner wall nearly to the bottom where the septae begin to widen and curve inward. Bottom of the calice flat with the septae extending inward as low, sharp crests for a distance equal to about 1-3 of the diameter. The central 1-3 of the bottom is perfectly flat and smooth.

Tabulae horizontal, deflected downward around the margins between the septae and the theca, about 1 mm. apart. A polished specimen 21 mm. long has 21 tabulae somewhat unevenly spaced.

[38] Op. cit.



78-A. Campophyllum gasperense. N. sp. natural size cluster of coralites. Top view. Usual appearance in the limestone.

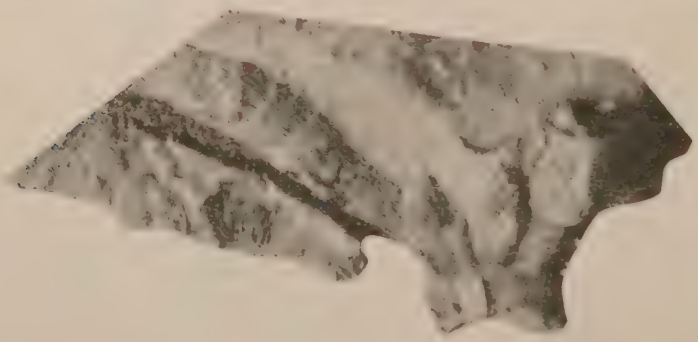
78-B. Reverse of 78-A, showing manner of growth from a central stock. Gasper oolite, McFadden Creek, 7 miles northwest of Bowling Green, Ky.

Septae alternating, wide and narrow, the primary ones extending inward about 1-6 the diameter nearly down to the bottom where they extend inward as far again as low, sharp crests on the surface of the tabulae. The secondary septae obsolete or obliterated in silification in most of the silicified specimens. A specimen 23 mm. in diameter has 36 primary and as many secondary septae, another specimen 32 mm. in diameter has 48 each primary and secondary septae.

The septae are all smooth on the edges and sides.

The counter and alar septae are not distinguished from the others. The cardinal septum, situated in a narrow, oblong fossula, is narrower than the others. The fossula extends inward 1-3 the diameter or to the inner edge of the ring of septae.

The extrathecal zone of interseptal vesicular tissue is about 1-6 the diameter of the interthecal space. The interseptal vesicular plates are ascending and slope outward to the epitheca.



78-C. Campophyllum gaspernse, N. sp. X-1½. Reverse of specimen shown in 78-D 2. Showing part of a circlet of coralites arising by budding.

The individual colonies of this species reach large size. A mass has been observed about 2 1-2 x 1 1-2 x 1 foot in diamensions with coralites projecting from the surface all around.

From its compound habit this species could easily be mistaken for *Lithostrotion proliferum* especially from the exposed ends of the coralites on a weathered surface of limestone.

Horizon and Locality. Lower part of the Gasper oolite in which it is distributed throughout Kentucky, Tennessee, Virginia and Alabama as described above.

78-D. Campophyllum gasperense. Cluster of coralites partly arising by budding from a single coralite at base of specimen. Reverse is shown in 78-C. Lower part of Gasper oolite, Cowan, Tenn.

Cypress Sandstone

Name. The name Cypress was given to the sandstone here under consideration by Englemann[39] in 1866. The name is from Cypress Creek, in Union County, Ill., where the sandstone is exposed in bluffs and cliffs. In Kentucky the sandstone was later called the "Big Clifty sandstone" by Norwood[40] in 1876. By the law of priority Cypress is the name that should prevail. The Cypress follows the Gasper, wherever exposures have permitted observations, without any evidence of unconformity. (See Plate 79.)

Distribution. The Cypress sandstone in Kentucky is mainly confined to the country west of the meridian of Louisville

[39] Englemann, Henry, Report on Hardin County, Ill. Illinois Geol. Survey, Vol. 1, p. 356, 1866.
[40] Norwood, C. J., Geol. Survey of Kentucky, New Series, Vol. 1, 1876.

Plate 79. View showing the contact of the Cypress sandstone and Gasper oolite. Ravine about 1 mile south of Livingston, Tenn. Looking south. No indications of erosion previous to the deposition of the Cypress here or at many other points in Overton County where this contact is exposed.

and north of the latitude of Bowling Green. It caps the bluff visible on the west and north from the Louisville and Nashville Railroad much of the distance from Munfordsville, Hart County, to Russellville in Logan County. It also caps a number of knobs lying to the south and east of the bluff, such as Pruits knob south of Cave City and the conspicuous buttelike knob south of Munfordville. (See Plate 80.) It is the sandstone forming the surface above the entrance of Mammoth Cave. It caps the high hills clear across Hart County. It is not present, however, in Green River Knob, in the south corner of Casey County, the sandstone capping that knob being Pottsville or "Coal Measures" sandstone. In the eastern outcrop of the upper Mississippian formations the Cypress sandstone is not present at Monticello nor north thereof to Ohio River. A section at Parmleysville, 12 miles southeast of Monticello, pub-

Plate 80. Knob or butte capped with Cypress sandstone. About 2 miles southwest of Munfordville, Hart County. Looking southwest. Slopes of Gasper and Ste. Genevieve (Fredonian) oolites, mainly the first named. This is an outlier from the main body of these formations, the east-facing escarpment of which is capped by the same sandstone and is shown in the distance.

lished by Munn[41], shows 10 feet of "thin-bedded, impure, curly ripple-marked fossiliferous" sandstone in limestone that may represent the Cypress, but it is not certain that it does. In the northeast corner of the Standingstone quadrangle, Tenn., in the northwestern corner of Fentress County, the Cypress is present and variable in thickness. At some points it is absent altogether, at others very thin (6 inches to a foot) of shaly calcareous sandstone, and at other points a thick-bedded sandstone 40 feet thick. It is particularly well developed in the northwestern one-fourth of the Standingstone quadrangle, in the vicinity of Livingston and to the northwest thereof.

Character. The Cypress sandstone is usually a thick-bedded to massively bedded sandstone, gray in color or somewhat iron stained in places. In the vicinity of Eastview station, in Hardin County, a part of the Cypress is massive and friable, weathering down into a clean white sand. In places, too, it is thin bedded and has strongly cross-bedded layers as in the locality

[41] Munn, M. J., U. S. Geol. Survey Bull. 579, p. 31, 1914.

of the photograph, Plate 79. In the vicinity of Sample and Stephensport, Breckinridge County, it takes on a shale facies and has very little sandstone. Some of the shale is red, but most of it is green.

Thickness. The Cypress sandstone from Breckinridge County south to Warren County varies from 50 to 80 feet thick. In Overton County, Tenn., it is in most of the areas where it is present about 40 feet thick. It is thinnest in eastern Overton and western Fentress counties, in the region nearest to Kentucky, so that its thin development or practical disappearance in Clinton County and southern Wayne County is in harmony with the condition and behavior a few miles to the south in Tennessee.

Correlation. The Cypress sandstone has been traced from the type locality in Union County, Ill., into central Kentucky closely enough to make sure of its identity throughout as far east at least as eastern Hart County, Ky., and north to Ohio River in Meade County, Ky. In the region between Hart County and the northwest corner of Barren County on the northwest and the northwestern corner of Overton County, Tenn., on the southeast is a gap of about 50 miles across Barren and Munroe counties, Ky., and Clay County, Tenn., which is not bridged by any known occurrence of the Cypress. It is possible and probable that it is carried in the top of some of the high knobs in Clay or Pickett counties, Tenn., or perhaps also in the western part of Clinton County, Ky. However, the position of the Cypress in Overton County, Tenn., immediately above the Gasper oolite, as the Cypress is in western Kentucky, strongly supports the identification of the Overton County sandstone as Cypress. This identification is corroborated by the further fact that locally in Overton County there is a second sandstone about 30 feet above the Cypress in the position of the Hardinsburg sandstone, which holds a similar position in Breckinridge County, Ky. In both the Tennessee and Kentucky localities the Hardinsburg or its horizon is succeeded above by the Glen Dean, and everywhere unmistakably identifiable limestone.

The Cypress is the same as the "Newman" sandstone lentil of the Newman limestone of the Standingstone and Wartburg folios of the U. S. Geological Survey, and is probably the same

as the Hartselle sandstone of Alabama. Both the Cypress and Hardinsburg sandstone extend clear or nearly across Tennessee, one being present in one locality, the other in another, and both being present in some localities, separated by 30 feet or less of shale and limestone. In places in Alabama, as in the vicinity of Bangor, Blount County, and Frankfort, Colbert County, a sandstone reaching a thickness of 5 feet, occurs 5 to 20 feet above the main body of the Hartselle, from which it is separated by clay and thin limestone. The upper sandstone is succeeded above by the Bangor limestone, which includes in the bottom the equivalent of the Glen Dean, so that the upper sandstone may be Hardinsburg, the clay representing the Golconda, and the main sandstone, the Hartselle, representing the Cypress. This is the writer's present interpretation.

Golconda Formation

Name. The Golconda formation was named from Golconda, Ill. It was agreed upon by a number of geologists interested in Mississippian stratigraphy in 1916, and was first used by Ulrich in 1915 in a paper read before the Geological Society of America, but not published. In its type locality and throughout western Kentucky the Golconda is definitely bounded below by the Cypress sandstone and above the Hardinsburg sandstone.

Distribution. The Golconda formation is present in Kentucky as far east as western Warren County, whence it extends north to Ohio River in Meade County. East of the Bluegrass region and of the Nashville basin in Tennessee its presence, although it is believed, is not so surely established. This belief is based on the presence of a thin bed of marly green shale containing streaks of red shale and in places some limestone. This shale overlies the Cypress in Overton County, Tenn., and in that county is beneath a second sandstone, locally present, correlated with the Hardinsburg sandstone. Where the lower sandstone is absent, as it is locally in the northwest corner of Fentress County, the shale directly overlies the Gasper oolite, and where the supposed Hardinsburg sandstone is absent the shale is overlain by the Glen Dean limestone. The stratigraphic relations of this shale are therefore strictly analogous to that of the Golconda formation. The shale is shown in the columnar

section of the Standingstone folio, No. 53 of the U. S. Geological Survey, where it is included in the Newman limestone. Moreover, about 3 miles southeast of Cowan, Tenn., on the railroad to Sewanee, a bed of shale and limestone 30 feet thick, carrying a fauna according to Ulrich of strong Golconda affinities, rests directly upon the Gasper oolite and is overlain by 8 feet of sandstone, which, in turn, is overlain by typical Glen Dean limestone. The sandstone therefore corresponds in position to the Hardinsburg. Furthermore, about 3 miles northeast of Cowan on a high spur, the limestone and shale similar to that southeast of Cowan and carrying some of the same fossils, is both overlain and underlain by thin sandstones corresponding in position to the Cypress and Hardinsburg. At Cowan tunnel, too, the limestone and shale supposed to be Golconda are thicker amounting to 58 feet with 23 feet of shale at bottom.

Although Cowan is about 115 miles south of the locality in Overton County where the supposed Golconda shale has been observed, yet the fact that the shale and limestone of probable Golconda age at Cowan is in the same sequence as that in Overton County and partakes largely of its character, justifies the correlation of the two.

Character. The Golconda formation in eastern Kentucky is mainly a soft green shale, which is present at the top of the Gasper in every section examined from Overton County, Tenn., to Carter County, Ky. In the southern counties it makes a bench on the slopes which doubtless is continuous into Tennessee, where it is a still more prominent feature.

In addition to the shale, there is in some sections, as between Somerset and Mt. Vernon and in the vicinity of the latter, a few feet of thick-bedded yellow limestone with *Archimedes lativolvis* or *A. swallowanus* and *A. Terebriformis* that may belong in the Golconda. The presence of Archimedes, which is very scarce in the Gasper, and the different character of these upper few feet of limestone from the typical Gasper, are the main reasons for thinking that the layers in question may be Golconda. If such is the case the place of the Cypress sandstone would be just underneath them.

Fossils and Correlation. The shale in the Golconda is unfossiliferous, and unless the yellow limestone layers are Golconda

it is without fossils in this region. The yellow limestone layers beneath the shale mentioned above have yielded the fossils of the following list:

Agassizocrinus sp.?
Pentremites sp.?
Archimedes lativolvis or *A. swallowanus.*
Archimedes terebriformis.

The material is mostly too poor for satisfactory determination. If the doubtful species is really *A. lativolvis*, it would support the idea that these beds are of Golconda age for that species is regarded as rather characteristic of the Golconda.

In June, 1922, and since the above was written a fortunate discovery by the author of *Pterotocrinus capitalis* in this shale and limestone bed at the north end of Lookout Mt., Tenn. has proven that the bed is Golconda. *P. capitalis,* hitherto known only in southern Illinois and Western Kentucky, is the most distinctive and reliable guide fossil of the Golconda.

Glen Dean Limestone

Name and Limits. The name Glen Dean was introduced by Butts[42] in 1917, from the village of Glen Dean, on the Fordsville branch of the Louisville, Henderson and St. Louis Railroad, in Breckinridge County, Ky. In western Kentucky the Glen Dean is definitely bounded above and below by persistent sandstone strata, namely, the Hardinsburg sandstone below and the Tar Springs sandstone above. East of the Bluegrass region it is bounded below by the Golconda shale and above by shale of similar character in the bottom of the Penington formation, or, where these beds are wanting, by the basal beds of the Pennsylvanian Pottsville sandstone. The Glen Dean is unconformable on the Golconda, through the absence of the Hardinsburg sandstone. Where it is unconformably overlain by the Pottsville, as from Kentucky River, northward into Carter County, stream channels were in places worn into its surface which were filled by the basal layers of the Pottsville. An

[42] Butts, Charles, The Mississippian formations of Western Kentucky. Kentucky Geol. Survey, p. 97, 1917.

example, illustrated in Plate 81, (frontispiece) is finely revealed in the south bank of Kentucky River just below the Government dam at Heidelberg.

Distribution. The Glen Dean is possibly the most widely distributed unit of the Chester Group. It extends from east to west the entire distance from Mississippi River in southern Illinois to Virginia, and from northern Kentucky to central Alabama. It is widely present throughout the region outlined, and is fairly uniform in lithologic character throughout and carries the same assemblage of fossils. Its outcrop west of the Bluegrass country lies through Meade, Breckinridge, Grayson, western Hart, Edmonson, and northern Warren counties; east of the Bluegrass country it outcrops high up on the knobs and spurs, close beneath the Pottsville or "Coal Measures," from the state line northward to Carter County, where a few feet of limestone of Glen Dean character are present directly beneath the Pottsville.

Character. The character of the Glen Dean is uniform in the regions covered by this report. It is almost wholly a thick-bedded to moderately thick-bedded predominantly blue, coarse-grained, fossiliferous limestone with some thin shale partings. Plate 81 gives an idea of its bedding character. In eastern Kentucky generally, near the bottom, is 10 feet or so of limestone that weathers shelly. This bed persists as far north as Owsley branch, east of Berea. There is considerable shale in the Glen Dean in places in Breckinridge County, as at and in the vicinity of Glen Dean, the type locality. At other points in the same county it is practically all limestone. At Sloans Valley, Pulaski County, it carries a bed of shale and thin limestone near the top that is highly fossiliferous and the source of the fossils of list No. 40, column 5. (See Plate 82.) At Pineville, Ky., Cumberland Gap, and Big Stone Gap, Va., it is a succession of limestone and calcerous shale beds underlying the Pennington formation. (See sections Nos. 45 and 46, section chart.)

Thickness. In Breckinridge County the Glen Dean is 100 to 150 feet thick. It is about 100 feet at Glen Dean. In the northwest part of Warren County it is about 50 feet. It is 140 feet in Overton County, Tenn., but only 63 feet at the north end

Plate 82. Glen Dean limestone and shale. North end of tunnel on the Cincinnati Southern Railroad at Sloans Valley, Ky. Looking south. This bed is the source of the many Glen Dean fossils obtained at Sloans Valley.

of Wray Hill, one mile south of Monticello, 35 feet at Mt. Vernon, and 48 feet on Kentucky River at Yellow Rock a few miles west of Beattyville. At Carter quarry is, in descending order, a 5-foot massive layer of limestone of Glen Dean character, 5 feet of marly shale, and below the shale about 3 feet of dark thin-bedded limestone, the whole resembling much more closely the Glen Dean than the Gasper. If this is Glen Dean it makes the full thickness exposed 13 feet. It may be somewhat but not much thicker, for Pottsville sandstone outcrops on the slope only a few feet above the limestone.

Fossils and Correlation. The Glen Dean is in localities highly fossiliferous and at some of these localities a great number of species have been collected. Probably the locality that has yielded the greatest number of species is Sloans Valley, in Pulaski County, where the material was derived from the railroad tunnel. (See Plate 82.) Collections from six localities distributed at fairly regular intervals from Mississippi River

to Cumberland Gap in southeastern Kentucky are listed. The lists, (except column 6,) and the distribution of the species are shown in the following table quoted from Ulrich Mississippian Series of western Kentucky, pages 226 to 230. Columns 1 to 6, one for each locality, are arranged in order from west to east. Column 1 is for Randolph County, Ill.; column 2,

LIST NO. 40.

List of Glen Dean Fossils from Various Localities Quoted from Ulrich Except Column 6.[1]

	1	2	3	4	5	6
Zaphrentis spinulifera Edwards & Haime		X	X	X		X
Acrocrinus shumardi Yandell				X	X	
Agassizocrinus conicus Wachsmuth & Springer	X	X	X	X	X	
Agassizocrinus gibbosus Hall	X				X	
Agelacrinites pulaskiensis Miller and Gurley	X			X		
Decadocrinus milleri Wetherby	X			X		
Eupachycrinus boydi Meek and Worthen					X	
Eupachycrinus gracilis Wetherby	X			X		
Eupachycrinus maniformis Yandell & Shumard					X	
Eupachycrinus spartarius Miller					X	
Hydreionocrinus depressus Wtherby (Hall?)						
Hydreionocrinus wetherbyi Wachsmuth and Springer					X	
Onychocrinus pulaskiensis Miller and Gurley					X	
Pachylocrinus spinfer Wetherby					X	
Pentremites angularis Lyon		X		X		
**Pentremites brevis* n. sp. Ulrich	X			X	X	X
Pentremites calycinus Lyon?				X		
**Pentremites canalis* n. sp. Ulrich	X			X	X	X
Pentremites cervinus Hall	X	X		X		
Pentremites cherokeeus Hall	X			X	X	
Pentremites clavatus Hambach	X			X		
Pentremites elegans Lyon	X	X		X	X	
Pentremites fohsi Ulrich	X	X			X	
Pentremites hambachi n. sp. Ulrich	X			X		
**Pentremites lyoni* n. sp. Ulrich	X	X	X		X	
Pentremites marionensis Ulrich		X				

[1] The fossils whose names are preceded by an * are confined to the Glen Dean.

	1	2	3	4	5	6
Pentremites n. sp. aff. *Pentremites obesus* Lyon					X	
Pentremites obesus modestus n. var. Ulrich		X		X	X	
Pentremites pyramidatus Ulrich	X	X	X		X	X
Pentremites pyramidatus var. planulatus n. var. Ulrich	X			X	X	
	X			X	X	
**Pentremites robustus hemisphericus* Ulrich				X	X	
**Pentremites robustus* Lyon	X				X	
Pentremites simulans n. sp. Ulrich	?X			X		
**Pentremites spicatus* n. sp. Ulrich	X			X	X	
**Pentremites subplanus* n. sp. Ulrich	X				X	?X
Pentremites tulipaeformis Hambach					X	
Poteriocrinus? anomalus Wetherby					X	
Poteriocrinus? pulaskiensis Miller and Gurley					X	
Poteriocrinus? vagulus Miller and Gurley					X	
**Pterotocrinus acuts* Wetherby	X			X	X	
**Pterotocrinus bifurcatus* Wetherby	X	X	X	X	X	
Pterotocrinus depressus Lyon and Casseday				X		
Pterotocrinus pyramidalis Lyon and Casseday		X			X	
**Pterotocrinus spatulatus* Wetherby					X	X
Pterotocrinus wetherby Miller and Gurley					X	
Scytalocrinus wachsmuthi Wetherby					X	
Scytalocrinus wetherbyi Miller					X	
Taxocrinus wetherbyi Miller and Gurley					X	
Zeacrinus cylindricus Miller and Gurley					X	
Zeacrinus durabilis Miller and Gurley				X		
Zeacrinus florealis Yandell and Shumard					X	
Zeacrinus kentuckyensis Miller and Gurley	X			X		
Zeacrinus magnoliaeformis Owen and Norwood				X		
Zeacrinus ovalis Lyon and Casseday					X	
Zeacrinus peculiaris Miller and Gurley					X	
Zeacrinus pulaskiensis Miller and Gurley			X			
Anisotrypa n. sp.	X	X		X	X	
Anisotrypa solida Ulrich	X	X		X	X	
Anisotrypa symmetrica Ulrich	X	X		X	X	X
Archimedes communis Ulrich	X				X	
Archimedes compactus Ulrich	X	X			X	X
Archimedes distans Ulrich	X	X	X		X	
Archimedes intermedius Ulrich	X		X	X		
Archimedes invaginatus Ulrich	X	X	X	X		
Archimedes laxus Hall	X	X	X	X		

	1	2	3	4	5	6
Archimedes meekanus Hall	X				X	
Archimedes proutanus Hall	X	X		X		
Archimedes cf. *swallowanus* Hall	X	X		X	X	
Archimedes tarebriformis Ulrich		X			X	
Batostomella abrupta Ulrich	X				X	
Batostomella nitidula Ulrich	X			X		
Batostomella sp.?	X	X			X	
Batostomella spinulosa Ulrich				X	X	
**Chilotrypa hispida* Ulrich		X				
Dichotrypa sp.?						
Eridopora aff. *marcrostmoa* Ulrich (has smaller zoocia)	X	X			X	
**Eridopora macrostoma* Ulrich	X			X	X	
Eridopora punctipora Ulrich		X	X			
Fenestella aff. *conradi* Ulrich	X	X	X		X	
Fenestella aff. *multispinosa* Ulrich	X	X		X	X	
Fenestella cestriensis Ulrich					X	
Fenestella cf. *compressa* Ulrich		X				
Fenestella elevatipora Ulrich				X	X	
Fenestella flexuosa Ulrich	X	X		X	X	X
Fenestella serratula Ulrich	X	X		X	X	X
Fenestella tenax Ulrich	X	X	X	X	X	
Fistulipora excellens Ulrich		X				
Fistulipora n. sp.		X		X	X	
Hederella sp.	X	X	X		X	
Lioclema arancum Ulrich	X				X	
Lyropora divergens Ulrich				X		
Lyropora ovalis Ulrich	X	X		X		
Lyropora quincuncialis Hall	X			X	X	
Lyropora ranosculum Hall	X				X	
Lyropora subquadrans Hall	X	X	X		X	
Meekopora approximata Ulrich	X	X		X	X	
**Meekopora clausa* Ulrich				X	X	
Meekopora n. sp.	X	X		X	X	
Polypora approximata Ulrich	X		X	X	X	
Polypora cestriensis Ulrich	X	X		X		
Polypora corticosa Ulrich	X			X	X	
Polpora spinulifera Ulrich	X	?		X		
Polypora tuberculata Prout	X		X	X	X	
Prismopora serrulata Ulrich				X	X	X
Rhombopora armata Ulrich	X	X		X	X	
Rhombopora minor Ulrich	X	X		X	X	

	1	2	3	4	5	6
Rhombopora persimilis Ulrich	X	X		X	X	
Rhombopora tabulata Ulrich	X	X		X	X	
Rhombopora teniurama Ulrich	X	X		X	X	
Septopora biserialis nervata Swallow Ulrich var.				X	X	
Septopora cestriensis Prout?	X		X		X	
Septopora decipiens Ulrich				X	X	
Septopora robusta intermedia Ulrich				X	X	
Septopora subquadrans Ulrich	X	X			X	
Sphragiopora parasitica Ulrich	X	X			X	
**Stenopora ramosa* Ulrich	X			X	X	X
Stenopora rudis Ulrich					X	
Stenopora tuberculata Prout	X	X	X	X	X	
Stictoporella? undulata Ulrich				X		
Streblotrypa distincta Ulrich	X		X			
Streblotrypa nicklesi Ulrich	X		X	X	X	
Streblotrypa subspinosa Ulrich	X				X	
Thamniscus furcillatus Ulrich	X			X	X	
Thamniscus ramulosa Ulrich	X			X	X	
Vinella sp.				X	X	
Camarophoria explanata (McChesney)		X				X
Chonetes chesterensis Weller					X	
Cliothyridina sublamellosa (Hall?)		X			X	X
Composita subquadrata (Hall)		X				X
Composita trinuclea (Hall?)						X
Crania chesterensis Miller and Gurley	X	X			X	
Diaphragmus elegans var. (Shumard)		X		X	X	
Dielasma cf. *formosa* (Hall)		X			X	
Dielasma shumardanum (Miller)		X	X			
Eumetria vera or *verneuliana* (Hall)?		X			X	X
Girtyella cf. *brevilobata* (Swallow)		X			X	
Productus ovatus Hall	X	X	X	X	X	
Productus scabriculus Martin?		X	X		X	
Reticularia setigera Hall	X				X	
Spirifer aff. *breckinridgensis* Weller		X				
Spirifer increbescens Hall	X	X	X	X	X	
Spirifer increbescens var. (very elongate)			X			
Spiriferina aff. *spinosa* (hinge very short)		X				
Spiriferina spinosa Norwood and Pratten	X	X				X
Spiriferina transversa McChesney	X	X				X
Spirorbis sp.		X			X	
Allorisma sp.			X			
Aviculopecten sp.		X				

	1	2	3	4	5	6
Bellerophon sp.		X				
Euomphalus sp. aff. *E. planodorsatus* Meek and Worthen		X				
Platyceras sp.		X			X	
Pleurotomaria n. sp. (related to *P. chesterensis*) Meek and Worthen		X				
Orthoceras sp. (small simple type)		X			X	
Bairdia cestrinsis Ulrich					X	
Beyrichia? simulatrix Ulrich				X		
Beyrichiella confluens				X		
Hollina radiata var. *cestriensis*				X		
Kirkbya oblonga var. Ulrich				X		
Kirkbya tricollina Ulrich				X		
Kirkbya venosa Ulrich				X		
Moorea granosa Ulrich	X			X		
Primitia granimarginata Ulrich				X		
Ulrichia emarginata Ulrich				X		
Phillipsia sp.				X		

Smithland, Livingston County, Ky.; column 3, Belleville Spring, 7 miles north of Princeton, Caldwell County; column 4, Grayson County; column 5, Sloans Valley, Pulaski County; and column 6, Cumberland Gap, Kentucky-Virginia. The names in this list preceded by an asterisk are known only in the Glen Dean. A few other forms as *Prismopora serrulata* and *Archimedes laxus* are rare in any other zone in the Chester group so that the occurrence of either makes it highly probable that the rocks containing it are Glen Dean. The Glen Dean of Cumberland Gap and Big Stone Gap underlies the Pennington and is represented in the Newman limestone. This fact is proven by the occurrence of the starred fossils in column 6, as well as by *Prismopora serratula*, which for practical purposes is a Glen Dean fossil. The Bangor limestone of Alabama also corresponds to or at least includes the Glen Dean. At Cumberland Gap and Big Stone Gap, Va., there are no representatives of the Cypress sandstone, Golconda formation, and Hardinsburg sandstone, so that there is between the Gasper oolite and the Glen Dean a stratigraphic gap or unconformity equivalent to

fully 250 feet of rock strata in southern Illinois, as can be seen by an examination of section No. 1, section chart. The Glen Dean may enter into the composition of the Maxville limestone of Ohio, but that limestone seems to be chiefly the equivalent of the Gasper oolite.

The Big Lime

The oil well drillers apply the name Big Lime to the persistent limestone underlying the "Coal Measures" of the eastern Kentucky coal field. It is the limestone outcropping as a conspicuous cliff along the west slope of Pine Mountain. It is generally recorded in well logs as in the neighborhood of 200 feet thick, although in some wells it is not recorded or the record is of such a character as to indicate that the limestone is absent and that it might be actually the fact for it may have been eroded away before the coal measures were laid down as is somewhat more fully explained beyond.

It is clear from the preceding description that the Big Lime is made up of the St. Louis limestone, Ste. Genevieve limestone, the Gasper oolite and the Glen Dean limestone.

Pennington Formation

Name and Limits. The name Pennington was introduced by Campbell[43] in 1893 from Pennington Gap, Va.

In Virginia the Pennington includes all the rocks of Mississippian age between the top of the Newman limestone and the base of the Pottsville rocks "Coal Measures." It has been shown that in that region the upper half or thereabouts of the Newman is of the age of the Glen Dean limestone.

Distribution. The Pennington of central Kentucky is limited to the western escarpment of the Cumberland Plateau and outcrops from the Kentucky-Tennessee line northward as far as the latitude of Berea, where it apparently feathers out. In Breckinridge County the Pennington of the eastern belt through Clinton, Wyane, Pulaski counties, etc., is represented by the Buffalo Wallow formation. (See Sec. No. 5 on large chart, etc.) The Pennington outcrops along the west face of Pine Mountain from the Breaks of Sandy to Tennessee.

[43] U. S. Geol. Survey Bull. 111, pp. 28, 37.

Character. The Pennington formation through Clinton, Wayne and Pulaski counties and to its northern limit is composed mainly of shale, but includes a smaller proportion of limestone and sandstone. The shale is largely soft, green, marly, but there are layers of red shale. The limestone is generally argillaceous, some is red, some is bluish, crystalline, and fossiliferous, some is light-gray and of lithographic texture when fresh. The sandstone is fine grained and usually laminated or shaly. The red color of the shale and limestone is characteristic of the Pennington from Virginia to Alabama and of the equivalent Buffalo Wallow formation of western Kentucky. It is a southern extension of the red color of the Mauch Chunk shale of Pennsylvania, to part of which the Pennington is equivalent.

Thickness. The greatest thickness of Pennington measured is at Monticello and Burnside where it is 140 and 135 feet respectively. The measurement at Burnside is especially reliable for both top and bottom could be seen there. The formation thins northeastward to 35 feet at Mt. Vernon, (Sec. No. 27, section chart), and about the same thickness seemed referable to the Pennington at Morrill, southeast of Berea, (Sec. No. 34, section chart.) To the northeast of Morrill the Pennington was not indentified. At Cumberland Gap the Pennington is about 200 feet thick and at Big Stone Gap, Va., is about 1,100 feet thick.

Fossils and Correlation. The Pennington in middle Tennessee and east-central Kentucky is not very fossiliferous and no fossils were collected from it in Kentucky or in Overton County, Tenn. In Breckinridge County, Ky., however, such characteristic upper Chester fossils as *Composita subquadrata* and *Spirifer increbescens*, very large, robust forms, occur in the equivalent Buffalo Wallow formation, and there can be no reasonable doubt that the east-central Kentucky Pennington is partly equivalent to the upper Chester of the Ohio and Mississippi Valleys, that is, it falls into that part of the Chester above the Glen Dean limestone and extends at least as high as the Clore limestone. Whether it includes in the lower part the equivalent of the Tar Springs sandstone is not determinable. The Pennington of the Pineville and Cumberland Gap sections

also probably extends at least as high in the section as the Clore limestone of Mississippi Valley, and at Big Stone Gap, Va., where it is about 1,100 feet thick, it may include beds in the upper part as young as any in the type region of the Mississippian series exhibited in section No. 1 of the section chart. The Pennington falls within the limits of the Mauch Chunk red shale of Pennsylvania and probably within the upper half or two-thirds of the Mauch Chunk.

Relations of the Chester Group to the Mauch Chunk Shale of Pennsylvania

The view has already been expressed, page 155, that the Ste. Genevieve limestone of central Kentucky is the equivalent of the Loyalhanna limestone of Pennsylvania, which lies upon the Burgoon sandstone (Pocono, Big Injun sand.) The equivalent of the Burgoon is the Logan formation of Ohio and Kentucky, which has been shown to be not younger than lower Burlington of Mississippi Valley. There is in Pennsylvania, therefore, between the Loyalhanna and the Burgoon sandstone, a stratigraphic break equal to the upper Burlington, Keokuk, Warsaw, and St. Louis formations of Mississippi valley, which are absent in Pennsylvania.

In Pennsylvania the nearest point to the Ohio and Kentucky outcrops of the Ste. Genevieve at which the Loyalhanna outcrops is on Chestnut Ridge, in Fayette and Westmoreland counties, in the vicinity of Connellsville. In that part of Pennsylvania and in western Maryland the Loyalhanna is immediately overlain by red shale, the basal Mauch Chunk, about 40 feet thick. The red shale is succeeded by the Greenbrier limestone lentil, some 50 feet thick in Pennsylvania but considerably thicker in Maryland. Above the Greenbrier limestone is more red shale extending up to the Pottsville sandstone. The whole is classed as Mauch Chunk, which, 100 feet thick or so in southwestern Pennsylvania, is only a fraction of the whole Mauch Chunk, which is 2,200 feet thick in eastern Pennsylvania.

The Greenbrier limestone is by its fossils correlated with the Maxville limestone of Ohio, which is in the main the same as

the Gasper oolite of Kentucky. If the correlation is correct it follows that the Mauch Chunk extends downward at least to the base of the Gasper, and probably the top of the Ste. Genevieve limestone. The top of the Mauch Chunk in the region of its maximum thickness should extend at least as high as the top of the Pennington of southwest Virginia and the top of the Chester of Mississippi and Ohio Valleys.

Unconformity Between the Mississippian and Pennsylvanian

As has been referred to in a number of places in the preceding pages, the Pennsylvanian ("Coal Measures") rocks, of which the basal part constitutes the Pottsville formation or group, rests upon different members of the Mississippian series in eastern Kentucky. From Wayne County to Rockcastle Co. the Pottsville is in contact with the Pennington; at the Pinnacle, 2 miles east of Berea, the Pottsville, here represented by the Rockcastle conglomerate member, the top formation of the Lower Pottsville, rests upon the Gasper oolite; on Kentucky River at Irvine and Heidelberg, on Morris Mountain, and at Olive Hill and Carter, it rests upon the Glen Dean limestone. At Rothwell, Menifee County, it rests on Ste. Genevieve or St. Louis at points not over one-half mile apart. At Deep Cut, on the Kinniconick branch of the Chesapeake and Ohio Railroad, 4 miles west of Carter, Carter County, the Pottsville is in contact with the Ste. Genevieve; and at Portsmouth it is in contact with the Logan formation, while at Limeville (Tongs P. O.), a few miles east of Portsmouth, 20 to 25 feet of Ste. Genevieve intervene between the Pottsville and Logan.

From the scattered data enumerated in the preceding paragraph it is plain that the Pottsville northward and eastward from southern Kentucky and westward from eastern Kentucky comes into contact with successively lower members of the Mississippian series from the Pennington down to the lower Burlington, (Logan).

The explanation is that after the deposition of the Mississippian series, which certainly extended a considerable distance westward over the Bluegrass region, nearly all of the central United States was raised above sea level and became land,

from which the Mississippian strata were beveled off by erosion so that different members of the series formed the surface of the land in different areas. Besides the general beveling, stream channels were entrenched in the surface as at the present time. After a time the Pottsville rocks creeping slowly westward from Virginia and West Virginia were laid down upon the old eroded surface, and naturally came successively into contact with older and older strata to the northwestward in the course of their transgression. The lower parts of the land and the old valleys were naturally first filled up. One of these old filled valleys has been fortunately uncovered by Kentucky River at Heidelberg, and the Pottsville rocks, with coal beds, filling the old channel are plainly revealed. A photograph of the filled channel in the Glen Dean limestone is exhibited in the frontispiece, (Plate 81.)

The general relations of the Mississippian and Pennsylvanian brought about by the activities outlined above are illustrated in Fig. 7.

Fig. 7. Diagrammatic section across the eastern Kentucky coal field from South Portsmouth south eastward. Shows the unconformable relation of the Mississippian and Pottsville (coal measures).

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